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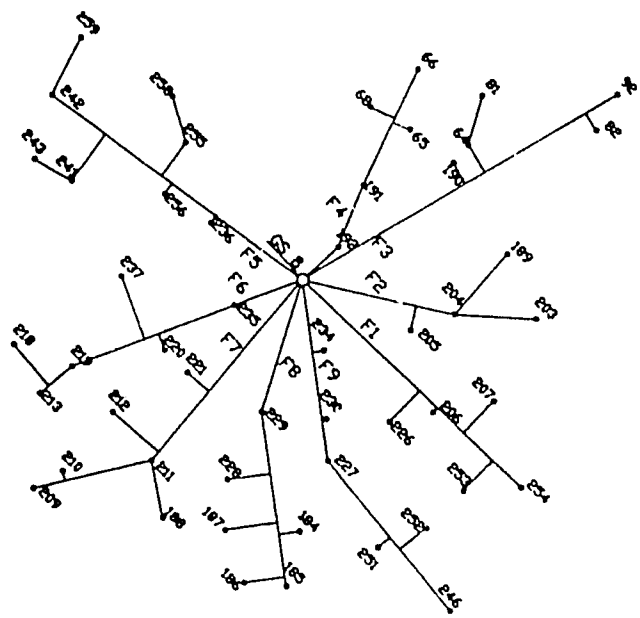
RURAL ELECTRIFICATION MASTER PLAN REVISION

Final Report
Project No. 391-0478
Contract PDC-5730-I-00-6110-00 #06

Prepared for

Government of Pakistan
and
U.S. Agency for International Development



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July 1988

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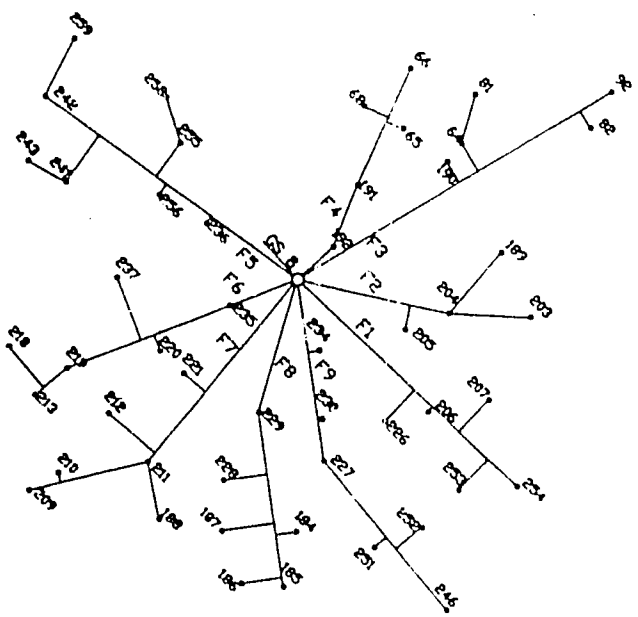

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PREFACE

This plan has been prepared for and in cooperation with the Rural Electrification Master Plan Revision Committee with representatives from:

1. Power Distribution Wing, WAPDA
2. Energy Wing, Ministry of Planning
3. Ministry of Water and Power
4. Irrigation and Power Department, Punjab
5. Irrigation and Power Department, Sind
6. Planning and Development Department, NWFP
7. Planning and Development Department, Baluchistan

The services of FACE Ltd. were provided under a subcontract to Mathtech, Inc. as part of ENERPLAN.

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EXECUTIVE SUMMARY

INTRODUCTION

This report presents a Revised Master Plan for Rural Electrification in Pakistan. It was prepared in accordance with an agreement between the Government of Pakistan (GOP) and the United States Agency for International Development (USAID).

In accordance with the agreement between GOP and USAID, this plan focuses on the strategic aspects of rural electrification (RE) development in Pakistan; and in accordance with this agreement the plan covers the following policy components of Pakistan's rural electrification policies:

1. definitions of rural electrification;
2. the institutional structures to implement the Government's rural electrification policies and programs;
3. policies regarding intensification or backfill (increased penetration in already electrified villages) versus extending the system to new villages/settlements;
4. consumer connection policy;
5. tariff policy;
6. subsidy policy;
7. village/settlement selection policy; and
8. technical standards and supply alternatives.

The Government has decided to provide electricity to all areas of the country as part of its national planning and socio-economic development programs. It is essential to fully understand that the implications of the different aspects of rural electrification policy are interrelated and must be considered in an integrated systems fashion. In policy deliberations the focus must cover not only the village/settlement selection policy but must encompass the greater consideration of all the other policy issues and consideration of their interrelationships.

DEFINITIONS (Chapter 1)

The definitions presented below are to be used to define areas in which the electrical supply and service shall be known as "rural electrification". The definitions acknowledge the distinctions between the provision of electricity supply and service to rural versus urban areas and customers. The definitions would be utilized to identify distinct administrative, area and functional responsibilities associated with continuing implementation of RE. The definitions and their applications to such tasks as classifying system customers, components and assets should clarify any ambiguities between rural electrification and other electrification activities.

Rural electrification is defined as consisting of both the supply of electricity to individual small towns, villages and subvillages in rural areas (as defined below) and the service of connecting customers in such rural areas. The provision of electric supply may be from either the grid or from decentralized electricity generation.

Rural areas for the purposes of electrification shall be defined in accordance with the census district categories. A rural area is any area so categorized in the census as rural. Exceptions from conformity to the census definition may be made in special circumstances as outlined in this report.

Defining the service of rural electrification and the areas which shall be classified as rural for the purposes of electrification are insufficient to define "rural electrification". It is necessary to further define what constitutes an electrified area, and to extend the definition to the existing electricity systems so as to identify rural components of the existing system.

The definition of an electrification area must incorporate measures of both settlements and population or households. A village should not be considered electrified when there are non-electrified subvillages which represent a substantial percentage of the whole village population. Nor should a village be considered electrified when only a small portion of the households within the village (all subvillages/settlements) have electric service. A village is defined as electrified when either:

1. a certain minimum percentage of the total village population, possibly 50%, is in electrified settlements/subvillages (the ECNEC committee ignores this measure, Ref 167); or

2. all of the village's settlements/subvillages with populations greater than a certain size are electrified (the ECNEC committee proposes 200 population or 25 houses as this minimum size),

   where a settlement/subvillage is defined as electrified when electricity has been made available to all customers and a minimum target percentage of all possible customers have been connected. The suggested target level is 70 percent; such high connection levels should be attainable through appropriate lifeline tariff and connection financing policies.

Distinctions between rural and urban customers and system components must be made so that the various technical, economic and financial distinctions can be made operational. For new customers and extensions of the system, new customers will be classified as rural if they are found in the areas so defined above. Similarly, for new or existing feeders lying totally in such rural areas these feeders will be classified as rural. In the case of feeders serving both urban and rural load it will be necessary to make subfeeder distinctions (and ultimately this may require subfeeder meters). In some instances it may prove convenient for administrative purposes to classify some existing feeders which serve both rural and nonrural consumers as rural if the feeder load is overwhelmingly rural.

THE CURRENT SITUATION AND SCOPE FOR IMPROVEMENT (Chapter 2)

The nature of rural electrification in Pakistan is changing and RE has become a major part of total WAPDA activities. The culture of rural electrification is different from that of urban electrification and it requires a different approach and different attitudes. While WAPDA has coped reasonably well with the RE program to date, it is evident that changes must be made to implement the new accelerated programs and to overcome some of the difficulties encountered on the financial, technical and institutional components of the program:

- o WAPDA cannot finance a national rural electrification program from its own resources. National policies on funding and subsidy will have to be developed. RE is basically a social economic program and must be planned in that context.

- o The total RE program assets, recurrent costs, and energy purchased and sold should be separately accounted and annual accounts prepared and published for each AEB and as a composite account for WAPDA.

- o Rural tariffs are inadequate and must be reviewed; load management programs must be implemented (especially for tubewells) and a special lifeline tariff (to cover all costs) must be developed for low-income customers.

- o Rural load promotion and public relations programs should be implemented to encourage wise use of electricity and to eliminate illegal payments and connections.

- o A customer data bank should be developed to integrate with present customer information systems to be used for load research, consumption patterns, account validation, etc.

- o A special crash program should be initiated to connect the potential customers in the villages already electrified. This would improve the return on investment and reduce the illegal payments and connections and eventually eliminate the backlog of customers awaiting supply (presently this figure is in excess of 0.5 million).

- o The present rural network design (which is based on urban distribution standards) is too costly for the load density and anticipated revenues in the rural system. A new low-cost reliable network must be designed incorporating such aspects as:
  - i. greater use of high-tension single-phase lines and transformers, and reduced lengths of low-tension networks (with three phase converters for 3-phase equipment);
  - ii. cheaper poles; and,
  - iii. more economically sized conductors, transformers and other equipment.

  Such changes could achieve savings up to 30 percent on existing costs, especially in new areas.

- o Chronic material shortages result in increased costs from low productivity and low morale, and must be eliminated.

- o Technical manuals outlining new designs, materials and standards can be very quickly prepared and should be implemented without delay.

- o New improved area design, costing and selection standards can also be readily established and the new rural electrification work program prepared and implemented by early 1989.

INSTITUTIONAL PROPOSAL (Chapter 2)

In order to implement this approach the Government of Pakistan needs to approve and implement new institutional arrangements, organizational structures, systems and procedures without delay. WAPDA presently acts as the implementing agency for Government on the present RE program and it is proposed that WAPDA continue to implement the RE program with the improved organization structures.

A new Rural Electrification Office (REO) would be established under a new General Manager reporting administratively to the Managing Director Distribution and also functionally to the Member Power on policy, strategic plans, financing and area selection. The feasibility of using cooperatives and/or private companies in the rural program would be considered from the outset. The REO would be small in size but very effective and influential and be fully discrete and self-contained on all the accounting, economic and technical functions. It would work with and through the total WAPDA organization on other functions. Ongoing construction would be carried out in the AEBs. A new position of Director of Rural Electrification would be created in each AEB and an Executive Engineer (XEN) construction unit would be fully dedicated to the rural program.

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These proposals for institutional change will complement the ongoing NAPDA USAID program and indeed will assist in accelerating the various institutional improvements proposed for the distribution function. In the longer-term the institutional changes proposed here can facilitate the possible eventual establishment of a separate National Distribution Authority with a number of decentralized Distribution Companies.

Pilot programs for rural cooperatives and private companies should be undertaken. In other countries, such alternatives has lead to savings in the construction, operation and maintenance of electrical supply and better connections. Cooperatives could be used for distribution and possibly decentralized generation. Private companies could be used for generation, distribution or both jointly. The new REO along with the Federal and Provincial governments should review the experience in other developing countries and develop initial guidelines, tariffs and regulations which would be tested in the pilot programs. Such guidelines must be designed with care to avoid the problems encountered in other countries.

POLICY CHANGES

A. Backfill Versus Expansion to New Villages (Chapter 3)

The future policy of the RE program, reflecting both equity and economic efficiency criteria, would emphasize intensification (backfill in already electrified villages) as opposed to primarily extending the system to new villages. This is different from the existing program which provides inadequate resources for new connections in villages/settlements already electrified. The characteristics of the policy to emphasize backfill would include:

1. Allocating (at least for the first 3 years, and then reviewed) half the RE budget for backfill.

2. The backfill budget policy will emphasize connecting households, commerce and industry located within the settlement, but not tubewells because of their currently highly subsidized position and the availability of an alternative energy source.

3. This policy is to be complemented by the consumer connection policy changes outlined in B below and the village/settlement selection policy changes outlined in E below.

B. Consumer Connection Policy (Chapter 3)

The consumer connection policy for the future RE program balances equity criteria with minimum financial solvency criteria and would include:

1. Minimum household target connections of 70 percent of the households in all electrified villages/settlements; this target will hold for both newly electrified villages/settlements and the increased backfill component of the program (see A above). This target is set to achieve equity goals of connections to all households. This policy should be coordinated with item 4. below in order that affordability to low income households is assured.

2. Adequate funds and materials (connection cables, meters etc.) to be made available to meet the 70 percent targets. This will reduce the scarcity of service connections and hence reduce unofficial payments.

3. Expansion of surveillance activities to monitor connection procedures and minimize unofficial connection payments.

4. Introduction of an addition to the RE program of a zero first cost (service connection) option aimed at low income households. This program would finance (either through loans or special fixed charge tariffs) both service and internal wiring and light fixture costs. This policy would be complemented and reinforced with the introduction of a "rural lifeline" tariff category (see C.1 below). This option would only be available to customers with current-limited service.

5. Requirements that all new tubewell connections be required to:
   i. be fitted with capacitors for power factor correction;
   ii. adopt the reinforcing new tariff category D-LM (see C. 2 below) and be fitted with the necessary load management and metering equipment;
   iii. bear the full cost of connection (partial finance will be an option under the new tariff);

6. An immediate crash program of implementing load management on all existing tubewells including the development of a retrofit program to accomplish the equivalent of number 5. immediately above, within the next 5 years, i.e. during the 7th Plan period.

C. Tariff Policies (Chapter 3)

The tariff policies should reflect financial, economic and equity criteria and must be considered in conjunction with the subsidy policies. The objectives of the tariff policies should include a minimum target of financial solvency for the rural component of the supplier (WAPDA) via immediate tariff changes. The equity criteria should be reflected in both the tariff design for low income households and the complementary budgetary transfers from Government to WAPDA. Economic criteria should also be reflected in the longer term development of tariff changes. Currently, tariff changes are the subject of:

i. ongoing WAPDA tariff rationalization planning projects; and,

ii. a tariff study financed by the Asian Development Bank.

The tariff changes outlined immediately below may need to be modified in light of the results of these two ongoing projects. Based on the master plan preparation, the following changes are needed:

1. Introduction of a new household tariff and service connection (see item B.4 above) category. This tariff, referred to as a "rural lifeline" tariff and service connection option would be aimed at low income households. The tariff and service would be characterized as follows:

   i. current-limited service of up to a maximum of about 0.2 KW; and
   ii. unmetered monthly flat rate tariff (to be further studied) for which the monthly charge could be based on a use rate of about 200 kwh per year. Load research and pilot programs could be used to determine the specifics of this tariff.
   iii. The cost of the service connection, internal wiring and basic light fixtures should be covered by a monthly financing program in order to increase customer penetration. The initial large cost should be eliminated, if necessary, to avoid inhibiting connections.
   iv. The purpose of the flat rate and the current limiter is to develop the lowest cost type of connection so as to minimize the financial and administrative burden on WAPDA while attaining high household penetration rates.

2. Revision of the tubewell tariff structure (as an immediate priority) to:
   i. Complement the new connection and retrofit policy (items B.5 and B.6 above);
   ii. Eliminate the flat rate option;
   iii. Introduce a new tariff category D-LM (Load Managed) for the only new tubewell connections to be allowed (see item B.2 above), this tariff to cover at a minimum WAPDA's full financial costs (recurrent and fixed) and to also apply to all future "retrofitted" connections;
   iv. Increase the charges in tariff category D such that:
      a. the energy charges at a minimum cover the full recurrent financial cost to WAPDA; and,
      b. the capacity charge at a minimum covers the full capacity financial cost to WAPDA.
   v. Introduce other changes to complement the changes in connection policies, i.e. B.5 above); this could require the provision of a loan, which would be repaid by an additional monthly loan repayment fee.

3. Increase all (but the new "lifeline") household tariffs:
   i. to recover a greater degree of the financial costs of service;
   ii. to capture the ability to pay among high income households by implementing an increasing block structure; and,
   iii. to ensure with a progressive tariff that commercial and small industry users will not have an incentive to use this tariff category.

4. Plan and implement continuing examination and revision of rural tariffs. This review would be aimed at increasing over time, all tariffs (except the rural-lifeline) towards economic (long run margina cost) tariffs if consumer capacity to pay is adequate. Such examination should consider the different impacts on the four province

D. Subsidy Policies (Chapter 3)

As in the case of tariff policies, subsidy policies will need to be consistent with the other ongoing studies. Subsidy policies should extend beyond the tariff policies, and in conjunction with the tariff policies, should be aimed at achieving overall financial solvency on the rural componen of WAPDA by providing reasonable financial returns on assets. The subsidy policy should have the additional focus of minimizing cross subsidization and must be based on detailed cost accounting so that the cost of rural electrification is clearly discernible on a totally disaggregated basis. The subsidy polices will need continuing additional analysis as the rural electrification cost accounting procedures are fully implemented. Some changes can be implemented now:

1. Initiate rural electrification cost accounting systems to allow detailed estimation of the full financial costs of rural electrification, including all capital costs, value of energy supplied and sold and all recurrent costs. This will enable rural accounts to be prepared for each AEB and a composite account for WAPDA.

2. Implement an annual recurrent costs budgetary transfer from Government to WAPDA to cover the identified financial losses now incurred from the rural electrification system. This financial principle should be introduced now. Necessary transfers to cover the subsidy should decrease as the needed tariff policy changes are implemented (items C.2 and C.3 above). Initially the transfers will be on a national estimate basis. As the detailed rural system cost accounting systems have been fully developed and implemented by the new headquarters REO and the AEBs, the necessary recurrent budget subsidies should be pinpointed at all levels in the distribution system.

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E. Village/Settlement Selection Policy (Chapter 4)

The village/settlement selection policies should combine both economic and equity criteria. The approach now proposed is an immediate extension of planning work that is presently being done to some degree at WAPDA headquarters and in the AEBs in coordination with the provincial governments. The technical and financial aspects of the approach should be a regular part of utility management. The suggested economic analysis is similar to and in some aspects simpler than what has been done in the past to examine some internationally financed RE projects in Pakistan.

In order to incorporate both economic and political inputs to the RE investment priorities for village selection, a two part process in recommended. The first part - budget allocation - is a set of procedures for allocating budgets from the Federal Government to the Provinces and then from the Provinces to the districts and/or tehsils. The second part - village ranking and selection within the district and/or tehsil budget allocations - is a planning procedure which ranks village-level investments on an area or cluster basis using benefit/cost analysis.

The procedure for budget allocations from the federal to provincial level should be studied to consider alternatives to the current one. Some alternatives that should be considered are rural population, numbers of rural villages, or numbers of un-electrified rural villages.

The proposed procedure for the budget allocation from provinces to districts is based on the rural population and the development potential in each district. The development potential would serve as an indicator of the additional benefits possible from electrification due to the prior existence of other district infrastructure such as markets, credit, literacy, roads, and industry.

This step-wise procedure is based upon judgements about the administrative and political environment and upon availability of data. Budget allocations and actual village selection should be implemented by the appropriate national, provincial, or local governments, while WAPDA (in the REO or AEB's) will conduct most of the necessary cost, benefit, demand, and other technical computations in cooperation with government agencies.

Once the national RE budget has been allocated to the district level, the village selection procedure includes analysis and procedures which consider the relative location of villages/settlements. Technical distribution line extension options should consider the village/settlement location both in relation to the grid and in relation to other villages/settlements. The objective is to maximize the net benefits achieved subject to a budget limitation.

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Effectively the approach maximizes electrical load, measured in economic value, per km of feeder. The selection procedure identifies the relevant area distribution line options including village/settlement connections. Su options constitute alternative discrete RE investment projects. The selecti procedure incorporates economic measures to rank and select from among these investment options (which may consist of the electrification of one, several or a cluster of villages/settlements). The selection is done in order of th ranking until the budget is exhausted. The technical and economic steps tha go into the approach are straight forward.

The village ranking procedures are designed so that an understanding of economics is not necessary at the field level; only technical and costing capability is required. The economic aspects are covered through parameters and calculation procedures that have been first laid out in the preparation this plan and can be updated and revised. Such updating will subsequently b the responsibility of the new REO. Until these procedures are well established, some villages may be selected using the present methods.

The important changes/revisions to policy are:

1. Immediate completion of the village/settlement data base to allow application of the area planning village/settlement to go forward in all AEBs.

2. Implement initial allocation of the National RE budgets to the Provinces and allocation of the Provinces' RE budgets to its districts in accordance with a revised procedure which weighs population and development potential. A study should be undertaken on initial revision of allocation procedures to Provincial districts for use in subsequent budgets.

3. Select (i) unelectrified settlements in villages which have had at least one settlement electrified and (ii) villages/settlements in unelectrified villages by the revised area planning analysis method detailed in Chapter 4. Investments in villages/settlements (or clusters of villages/settlements) to be selected starting from the highest economic Benefit/Cost (B/C) ratio (even if less than 1) and proceeding in the order of decreasing B/C until the area budget is exhausted.

F. Technical Designs and Standards (Chapter 5)

The policies with respect to technical designs and standards and supply alternatives must reflect technical options evaluated in the light of economi costs and benefits. These policies should achieve a goal of finding Pakistan solutions to the problems of RE in Pakistan by drawing as much as possible on the past experience both in Pakistan and other countries which have addressed similar problems.

WAPDA's existing rural distribution network is based on the choice of 11 kV as the primary voltage, extensive use of steel lattice structures for construction of both primary and secondary lines, three phase transformers ranging between 25 and 200 kVA and separate service cables to each customer. An extensive network of low tension distribution lines is already in existence. The networks have high technical losses and poor service quality and reliability. This is a high cost network compared to many other countries and an alternative solution has to be found.

In this connection, the main areas studied include the choice of a higher (33 kV) primary distribution voltage, introduction of single phase option on all branch lines, selection of conductors on the basis of economic criteria and demand in year 10, reduced length of LT lines, utilization of more approximately sized transformers, which can be justified in economic terms, introduction of smaller single phase transformers, multiple service cables and low cost prestressed concrete poles. The current movement in these directions by WAPDA should be supported.

Selection of 33 kV as primary voltage will result in overall cost reductions in capital investments in transmission, grid stations and distribution network expansion in spite of the fact that the 33 kV distribution network is more expensive than 11 kV, but considerable savings are possible in the costs of transmission, and the reduction of grid station and distribution losses.

The single phase option is economically viable on all branch lines. This option is more economical than the current 3-phase arrangement especially for electrification of individual loads such as tubewells. Replacement of 3-phase LT lines by single phase HT lines (specially 33 kV) in combination with phase converters for three phase motors is an attractive solution that results in substantial cost savings and should be examined in detail.

Smaller single phase transformers can be useful in avoiding waste of transformer installed capacity and reduction of losses. Multiple service connection cables offer another cost saving solution.

The existing steel lattice structures unnecessarily increase the cost of distribution lines. The existing prestressed concrete poles are not the optimum poles for rural distribution expansion. Introduction of low cost pole options can result in cost reductions on the order of 35%. Coupled with cheaper conductors used for 33 kV, the overall cost of HT distribution line construction can be reduced by a total of about 50%.

Application of a new cost effective approach, using the above outlined measures, can result in cost reductions close to 40% of the total capital investment, as may be seen from the application in a sample area in Pakistan.

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The major cost savings (+), as well cost increase (-) in the sample are were as follows:-

o Transmission & grid stations	+ 55%
o HT distribution lines	+ 61%
o Distribution transformers	- 14%
o LT lines	+ 28%
o Multiple service connection cables	+ 15%
o Regulators and Capacitors	- 87%
- Overall Cost Savings (weighted average)	+ 38%

These savings can be brought about by the introduction of 33 kV three phase (main lines) and single phase (branches) HT distribution lines, 5-25 kVA single phase transformers, multiple service cables, low cost prestressed concrete structures, 132 kV transmission lines and 132/33 kV grid stations.

From these studies it is now possible to prepare preliminary Technical Instruction Manuals outlining the new materials and methodology for introduction of the New Approach to Rural Electrification. In order to gai momentum, work on preparation of detailed technical specifications, product descriptions, standards, guidelines and procurement documents for the new equipment (33 kV, single phase smaller transformers, low cost poles etc.) a materials, must be started immediately.

One of the most important conclusions of the study is that WAPDA should immediately stop further procurement of steel lattice structures. The existing WAPDA and private sector prestressed concrete pole manufacturing capacity should be increased on a crash basis to meet the total requirements of distribution construction. The existing suppliers of steel lattice structures may either be encouraged to utilize their production capacity fo transmission line towers or put up prestressed concrete pole manufacturing plants.

Furthermore, there are major opportunities for the private sector in Pakistan for manufacturing of single phase transformers, voltage regulators, phase converters and power factor correction equipment.

To implement and update the new technical standards and guidelines on a continued basis, the capability within WAPDA Distribution must be developed.

In summary, the policy changes needed include:

1. Immediate issuance of a set of preliminary technical standards and guidelines to the AEBs (based on the work summarized above and detail in Chapter 5 and supporting Appendices) to facilitate the achievemen of cost reductions of 30 percent or more;

2. The incorporation of these technical guidelines in the area planning, costing and selection procedures and also in the work order implementation procedures for RE village/settlement investment projec preparation and execution;

3. The new rural electrification standards should be implemented within FY 1988/89 for at least a part of the GOP financed and the entire donor funded rural electrification program; and

4. Start of ongoing further studies to develop a final set of technical design and standards guidelines for rural electrification in Pakistan that can be readily implemented at the AEB Division level staff.

IMPLEMENTATION STRATEGY (Chapter 7)

The overall strategy outlined is designed to:

(1) Provide a fast-start to the program;

(2) Ensure the commitment and participation of the newly appointed managers at an early stage and to familiarize them with the special requirements of rural electrification;

(3) Have the new organization and advisors in place at an early stage and ensure that a vigorous initial thrust is provided; and,

(4) Have the new style RE program fully operational by 1990.

When aggregated into a total plan, the various proposals made represent changes in Government policy and WAPDA operations. The realities of the present work-load in WAPDA and its capacity to undertake and effectively implement this program must be considered.

It is proposed that external assistance will be necessary to help the new REO and other WAPDA staff, comprised of short-term consultants which could be appointed immediately to develop and implement preliminary guidelines, procedures and instruction manuals to plan, design, select and construct rural projects in the "New" format. The short-term consultants will help to set up the new organization, work with the new managers and help them to prepare terms of reference for the recruitment of a team of advisors to work with them in hands-on counterpart roles.

The program requires an effective implementation strategy to ensure that the short-term priorities are addressed, that issues having a longer-term perspective are initiated and that the impetus already gained is not lost in a period of relative inaction. Arising from the detail of the studies and analysis outlined in the report it is now evident that an immediate program of implementation can be started based on preliminary manuals which can be quickly provided.

It is proposed that 25% of the 1988-89 budget for rural electrification should be earmarked for implementation under the new procedures. This program would comprise 750 new villages and intensification/backfill of at least 750 already electrified villages. Additionally it is considered that all projects proposed for funding by the international development agencies would be planned and designed using only the new procedures. There are four main stages in the implementation process:

A. The priority work as outlined above and in Section 6.3 to apply the new procedures and guidelines to approximately 25 percent of the Government financed (and 100 percent of the externally financed) 1989 RE budget.

B. The installation of new organization structures and the appointment and induction of the managers.

C. The initial stages of the design and implementation of new systems and procedures including staff communication and training programs.

D. The consolidation of the new organization and new systems into the ongoing work in the distribution function.

It is proposed that stages A-C can be started immediately and completed by the end of March 1989. The detailed program for this is outlined in Chapter 7. Stage D would be planned for implementation in the period April 1989 to December 1990 and a detailed implementation plan for this phase will be prepared by the new REO manager in the period January 1989 to March 1989.

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Chapter 1

Introduction and The Definition of Rural Electrification

1.1 Introduction

This report presents a Revised Master Plan for Rural Electrification (RE) in Pakistan. It was prepared in accordance with an agreement between the Government of Pakistan (GOP) and the United States Agency for International Development (USAID).

In accordance with the agreement between GOP and USAID, this plan focuses on the strategic aspects of rural electrification development in Pakistan. The plan starts with definitions that are necessary to distinguish rural electrification from other electrification activities and then address the various institutional, financial, socioeconomic and technical issues relevant to rural electrification. The overall thrust of the plan is strategic in that it emphasizes approaches and criteria to be used in making choices, as well as changes and reforms that will facilitate more effective and efficient RE program development. Actual implementation of rural electrification expansion will require additional detailed planning employing the approaches and criteria presented in this report.

Like other components of the power sector, expansion of the rural systems requires planning and monitoring on a continual basis. In this strategically focused rural electrification master plan, decision criteria and planning approaches are presented, the parameters to be used in the planning approaches are estimated, and the initial applications of the criteria and approaches are made. In addition, this plan proposes a revised institutional framework that will facilitate:

1. actual rural electrification investment and project implementation; and,

2. the necessary continuing planning process.

It is anticipated that planning for rural electrification expansion will now become a distinct and important ongoing element of power sector planning in Pakistan. In order to succeed, the planning process will have to make extensive use of the approaches and criteria presented in this plan for implementation decisions. The criteria, approaches and planning parameters estimated by the team which prepared this initial strategic plan will also be periodically refined and revised as part of the ongoing planning effort.

The ongoing planning of rural electrification requires a clear definition of the activities which distinguish it from other power sector activities. These definitions are presented in the following sections of this Chapter.

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1.2 Purpose of Definitions

There are two definitions which need to be made explicit as part of the rural electrification revised master plan:

1. the definition of rural areas (for the purposes of rural electrification); and,

2. the definition of rural electrification itself.

Related to the second of these definitions is the additional issue of:

3. how to determine when a rural area, village or subvillage is electrified.

These definitions should be used by WAPDA, the Government of Pakistan, the Provincial Governments and other agencies and institutions for various identification purposes. The definitions should be used to define areas in which the electrical supply and service shall be known as "rural electrification". These definitions help to clarify the distinction between the provision of electricity supply and service to rural and urban areas and customers.

The definitions should be utilized to identify distinct administrative, area and functional responsibilities associated with continuing implementation of rural electrification in Pakistan. The definitions, and their applications to such tasks as classifying system customers, components and assets (see below) should clarify any ambiguities between rural electrification and other electrification activities. Criteria used in constructing the definitions included that:

i. the definitions should be in concurrence (if possible) with existing administrative definitions in use in Pakistan; and,

ii. the definitions (and their applications) should facilitate better administrative, technical and financial management of ongoing rural electrification activities.

These criteria are considered more relevant to the situation in Pakistan than criteria incorporating voltage, load density or other technical characteristics.

1.3 Definition (for the purposes of identification) of Rural Electrification

Rural electrification shall consist of both the supply of electricity to individual small towns, villages and subvillages in rural areas (as defined below) and the service of connecting customers in such rural areas. The provision of electric supply may be either from the grid or based on decentralized electricity generation.

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1.4 Definition (for purposes of identification) of Rural Areas for the purpose of electrification.

The definitions shall be derived from a combination of public administration and geographic/demographic units rather than power system distribution units such as a feeder area. In addition, the definitions should be utilized to classify feeders and other components of the supply system as outlined below. The starting point should be the current administrative definitions of urban versus rural areas which will then be integrated into the geographic/demographic units measuring population.

The national census classifies all areas into two categories: urban and rural. Since the census is the official source of population figures, it should also be the primary basis in the definition of rural areas for the purpose of electrification:

> Rural areas for the purposes of electrification shall be defined in accordance with the census district wise categories. A rural area is any area so categorized in the census as rural. Exceptions from conformity to the census definition may be made in special circumstances as outlined below.

District council area categories do not always coincide with census area categories partially due to the dynamic of population growth and settlement developments. Within a district, an area is classified (by the district council) as urban if it is administered by a municipal council. Areas administered by the union councils are considered rural. In general, there will be equivalence between urban and rural as defined by census and by the district councils. Hence, the equivalence of district council and census categories suggests that: for the purposes of rural electrification all areas covered by a union council are considered rural. There is, however, a middle ground which consists of areas covered by town councils. Most district council defined town council areas will fall in the census' urban category. In some instances, if these town council areas are only recently defined or if the towns are small and relatively isolated it may be appropriate to make an exception from the census based definition and define some such town council areas as rural for the purposes of rural electrification.

1.5 Extensions and Applications of the Definitions

Defining the service of rural electrification and the areas which shall be classified as rural for the purposes of electrification is not sufficient. It is necessary to further define what constitutes an area being electrified and to apply the definitions to classifying the existing electricity systems so as to identify which components of the existing system should be considered part of the rural system.

When is a rural area electrified? The basic units establishing whether an area classified as rural according to the above definition is considered electrified must also incorporate measures of both settlements and population or households. A village should not be considered electrified when there are subvillages which are not electrified and these non-electrified subvillages represents a significant portion of the village population. Nor should a village be considered electrified when only a small portion of the households within the whole village (all subvillages/settlements) have electric service. For the purposes of incorporating both the settlement and the population/household characteristics, it is suggested that for a village to be considered electrified one of the following must hold:

1. a certain minimum percentage of the total village population, possibly 50%, is in electrified settlements/subvillages (the ECNEC committee* ignores this measure); or

2. all of the village's settlements/subvillages with populations greater than a certain size are electrified (the ECNEC committee proposes 200 population or 25 houses as this minimum size).

   (where a settlement/subvillage is defined as electrified when electricity has been made available to <u>all</u> customers and a minimum target percentage of all possible customers have been connected. The suggested target level is 70 percent; such high connection levels should be attainable through appropriate lifeline tariff and connection financing policies.)

How to classify customers and the system assets? Distinctions between rural and urban customers and system components must be made so that the various technical, economic and financial distinctions, discussed elsewhere in this report, can be made operational. For new customers and extensions of the system, new customers will be classified as rural if they are found in the areas so defined. Similarly for new or existing feeders lying totally within such rural areas these feeders will be classified rural. In the case of feeders serving both urban and rural load it will be necessary to make subfeeder distinctions (and ultimately this may require subfeeder meters). In some instances, it may prove convenient for administrative purposes to classify some existing feeders which serve both rural and non-rural consumers as rural if the feeder load is overwhelmingly rural.

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* Committee Constituted by ECNEC to Evaluate the Implementation of Rural Electrification Program (minutes of meeting 11-2-88, reference 167)

1.6 Summary

The definition of an electrification area must incorporate measures of both settlements and population or households. A village should not be considered electrified when there are non-electrified subvillages which represent a substantial percentage of the whole village population. Nor should a village be considered electrified when only a small portion of the households within the village (all subvillages/settlements) have electric service. A village is defined as electrified when either:

1. a certain minimum percentage of the total village population, possibly 50%, is in electrified settlements/subvillages; or

2. all of the village's settlements/subvillages with populations greater than a certain size are electrified,

   where a settlement/subvillage is defined as electrified when electricity has been made available to all customers and a minimum target percentage of all possible customers have been connected. The suggested target level is 70 percent; such high connection levels should be attainable through appropriate lifeline tariff and connection financing policies.

Distinctions between rural and urban customers and system components must be made so that the various technical, economic and financial distinctions can be made operational. For new customers and extensions of the system, new customers will be classified as rural if they are found in the areas so defined above. Similarly, for new or existing feeders lying totally in such rural areas these feeders will be classified as rural. In the case of feeders serving both urban and rural load it will be necessary to make subfeeder distinctions (and ultimately this may require subfeeder meters). In some instances it may prove convenient for administrative purposes to classify some existing feeders which serve both rural and nonrural consumers as rural if the feeder load is overwhelmingly rural.

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Chapter 2

Institutional Issues

2.1 Introduction and the Current Institutional Structure

In Pakistan, Rural Electrification is a Federal Government responsibility. Provision of financial resources for capital expansion (only) comes from the development budget with additional financing from various international agencies. Provincial Governments have historically played an important role in the selection of villages for electrification. In addition, in the case of the Punjab, there was previously also a co-financing program under which villages could finance their connection and the Provincial Government would share in this cost. This program is no longer active.

WAPDA is the executing agency for rural electrification, it is responsible both for the construction of system expansion and continuing operation and maintenance. (The current executing structure is discussed further in section 2.2.3 below). In Pakistan, most urban and rural electrification is done as an expansion from the grid, though there are some isolated systems operated by WAPDA. In addition there are some small systems built and operated by other entities.

In the course of WAPDA's development, the rural load and rural customers have played a small part in the overall system and little or no separate institutional structures have been set up to deal with rural electrification other than material procurement and some limited planning. Rural electrification is handled as part of the overall distribution functions both at headquarters and in the AEBs. However, a rural electrification unit was organized to provide special arrangements for particular projects financed by external agencies. The overall philosophy and approach to rural electrification is predominantly urban distribution based and a specific directed approach to the special requirements for rural electrification has not been developed.

The role of rural electrification in the overall system is changing dramatically. As the objectives of the former Prime Minister's program of bringing electricity to all the people are met, the rural consumers will number in the many millions and will outnumber urban consumers. Yet the load characteristics of these rural consumers are different from those of urban consumers, and the technical and administrative options that can be cost effectively used to serve these consumers differ from those of urban consumers. These differences between rural electrification and the urban aspects of the system have been recognized by senior management of WAPDA as has been the need to provide an organizational structure responsive to these differences. Section 2.3 below outlines such an institutional structure

for WAPDA. Implicit in this proposed organizational change is a continuity of primary responsibility by WAPDA for executing the Government's rural electrification program.

2.2 Major Issues

Under the existing arrangements WAPDA has made significant progress in achieving national targets of rural electrification. The knowledge and experience gained to-date will be most valuable in planning and implementing an accelerated RE program to achieve targets such as those suggested by the former Prime Minister's program.

In order to cope with this increased work-load and to further improve performance, new institutional arrangements will be required and some major institutional, financial, economic and technical issues will have to be addressed. These issues and problems to be addressed are outlined immediately below and in some instances tentative solutions are proposed. Many of these points are examined in the later chapters of this report. Among the major issues and problems are:

- WAPDA cannot finance a national rural electrification program from its own internal resources.
- Present tariffs are inadequate to cover recurrent costs and do not adequately reflect the nature of the various loads being supplied.
- Load management programs are required for rural loads, particularly tubewells, and this should include peak-use limitations and improved power factors.
- Rural customers should be separately classified by type of load, usage etc. and a customer data bank developed which can be used for load research, consumption patterns and revenue validation and collection.
- Rural capital assets and rural operating costs should be separately allocated. Rural feeders and loads should be separately metered and energy costs allocated.
- Separate annual accounts for rural electrification should be prepared for each AEB and a composite account for WAPDA; these accounts should be outlined in the WAPDA annual report and annual statistical update.
- Rural load promotion should be developed and a customer communications program initiated using TV, radio, newspapers, flyers, etc. to promote wise use of electricity, to improve revenue collection, eliminate illegal payments etc.

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- A special crash program should be started to connect potential customers in villages already electrified. This would greatly improve the return on existing investment, reduce back-log of connections currently exceeding 0.5 million and reduce illegal connections and illegal payments.

- A special life-line tariff for low-income customers should be implemented using current-limiters and based on a standing charge to cover consumption, connection fee and house wiring.

- The present capital cost of the rural network is high relative to load density and anticipated revenue. This network design is based on standard urban distribution network design and is not entirely suitable for a rural distribution network.

- A new low-capital, low-maintenance cost rural electrification network will have to be designed with greater use of 33 KV and 11 KV single-phase lines, small single-phase transformers, reduced lengths of LT networks, cheaper poles, standardized conductor sizes, use of insulated conductor etc.

- Technical manuals outlining the new design, materials, construction methods, etc. should be prepared and a crash training program initiated.

- Material shortages are a cause of excessive delays, increased costs, low productivity and low staff morale. A special program to eliminate these shortages should be developed.

- New transformer protection arrangements will have to be developed to reduce excessive transformer burn out rate.

- There will be improved opportunities for local manufacturers to participate in the new rural electrification program on pole manufacture, single-phase transformers, power factor capacitors, phase convertors for using 3-phase motors on single-phase supply, current limiters etc.

- Rural electrification is basically a social program and must be planned within a framework of national and provincial development plans and policies including the necessary financing and funding arrangements.

- WAPDA presently acts as the implementing agency for the Government's national program and should prepare and implement plans (in accordance with criteria agreed upon by Government), develop projects, document all the procedures and information systems to ensure effective implementation and regulation of the activity.

- WAPDA would need to improve the present organizational arrangements to manage and implement the RE program both at the headquarters level and at the AEB level.

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- Rural electrification has a separate culture from urban electrification and requires different approaches and attitudes.

- There should be a new approach to RE and the experience in other countries both developed and developing should be examined to establish the best solutions for RE in Pakistan.

- The experience of other countries on the use of cooperatives and private generation and distribution companies should be examined as these options may be relevant in some areas in Pakistan.

All of these issues, problems, initial proposals and recommendations represent a step-change in existing attitudes, outlook and practice. The new institutional arrangements that are necessary, together with the urgent need to develop standards and new systems and procedures make it likely external expert assistance will be required at the outset.

2.3 Institutional Structures for Future Execution of Rural Electrification

2.3.1 Organizational Alternatives

Other countries have acknowledged the important distinctions between rural electrification programs and those for the urban and industrial components of the power system. These countries have employed a range of organizational approaches to deal with rural electrification. Among these organizational alternatives are:

1. A National Rural Electrification Authority;

2. A Department within a Government Ministry;

3. A Special Department within a Power Utility;

4. A Sub-Department of the Distribution Department of the Power Utility;

5. Rural Cooperatives; and,

6. Combinations of the above.

2.3.2 Organizational Requirements and Functions

Worldwide experience has shown that while the form of the organizations and of the institutional arrangements may vary there are three primary requirements of the necessary institutional structures:

- The RE organization must be clearly functionally separated from the other activities in the power utility;

- The RE organization must be a strong organization, discrete and self contained; and,

- The technical and financial systems and procedures must be designed specifically for the requirements of RE.

The RE organization would have to work within a framework of national policies and strategic plans for RE with agreed national criteria for expansion of the rural system and clear financing policies and procedures. (The initial framework of such expansion criteria and the financing policies are outlined in subsequent chapters of this report.) The main functions to be implemented by the RE organization would include:

i. Policy Formulation and Central Planning;

ii. Project Planning, Standards and Controls (Standard Operating Procedures);

iii. Finance - Financial Planning, Budgets, Cost Control, Returns on Investments etc.

iv. Load Promotion, Commercial Matters, Customer Load Research and Forecasts;

v. Design, Standards, Costs, Implementation and Construction;

vi. Maintenance and Operation Policies and Procedures; and,

vii. General Services.

2.3.3 An RE Organization in the Context of Power Sector Development

The appropriate RE organizational structure in Pakistan must be considered in the context of the existing and evolving organizations in the power sector. The current WAPDA distribution organization is undergoing strengthening. In the longer term, the development of the power sector could entail having a separate National Distribution Authority acting as the national central regulatory and control agency with separate area electricity boards having complete autonomy for all distribution and customer functions in their area.

Presently Distribution in WAPDA is experiencing serious problems coping with the total Distribution work load which includes RE activities; the WAPDA-USAID project is aimed at improving overall performance of distribution functions in WAPDA, both at headquarters and the AEBs. This improvement includes the development of new organizational arrangements with functional units for:

i. Planning;

ii. Administration;

iii. Purchasing;

iv. Management Services;

v. Finance;

vi. Customer Services; and,

vii. Area Operations (the AEBs).

Rural electrification in WAPDA is currently carried out within the above listed headquarters and AEB structures. There is some technical direction and support from the Head office - using mainly the normal distribution urban standards and procedures- but the main work of construction, operation, maintenance and development and intensification (back-fill service connections) is implemented by the AEBs. These RE activities are done through the Division/Circle organizations. After selection of villages for electrification (with directions from the Provincial Governments), at this AEB level, there is no differentiation (other than selection and funding) between RE construction operation and maintenance and Urban Distribution activities.

Limited project planning is done at headquarters, but again within the existing urban systems and procedures; and in any event a major influence on the distribution network development is provincial decisions to electrify specified villages. Within these organizational constraints, local pressures, lack of finance, chronic shortage of materials and lack of central policy and direction the AEB/Circle organizations have performed reasonably well to date. Improvement is needed and organizational changes are required to ensure continued improvement and to develop the necessary changes in systems, approach and attitudes which are specific to Rural Electrification. But such an organizational change responsive to the distinct needs of RE should be compatible with the institutional changes and strengthening programs underway assisted by the WAPDA-USAID project and also must be compatible with the possible longer-term autonomy for separate local distribution entities under a central regulatory control agency. Such an organizational change is outlined immediately below.

2.4 A New Organizational Structure for RE

It is now considered necessary to create a new separate organizational unit to provide the needed RE specific central direction and support. This unit would be located in WAPDA as a part of the Distribution function thus integrating with the possible long-term development of a separate Distribution Authority and also with the ongoing Distribution improvement program assisted by USAID.

The new central unit would be titled the Rural Electrification Office (REO) and would be headed by a General Manager reporting functionally to the Member Power and administratively to Managing Director Distribution. The reporting arrangement to Member Power would be concerned with:

- o policy development;
- o village selection procedures;
- o strategic plans; and
- o financing functions.

When the unit is fully operational and effective the necessity for this arrangement of reporting to Member Power can be reviewed. The GM REO would also report to and work with the MD Distribution on the other functions of:

1. RE technical standards and procedures;
2. RE commercial, load research and forecasting and customer-related functions;
3. Construction plans and implementation including decentralized generation; and
4. RE maintenance and operation standards.

This central unit would develop the policies and plans, manage the finance, develop new/unique standards practice and procedures for RE in Pakistan (especially for construction), implement separate cost accounting arrangements and customer/load research and forecasts. (The need for new and distinct technical standards are shown in Chapter 5 below). The new RE headquarters unit would be a small but very influential organization and would prepare the various instruction manuals (technical, administrative and financial) for implementation by the AEB/Circle organization. Management information systems would be installed to provide feed-back on data and performance.

As done in other countries such as the Philippines, it should be considered that the responsibility for decentralized generation be placed in the Distribution Wing under the new REO. This arrangement would likely facilitate the implementation of attractive decentralized generation. However, this arrangement would also require coordination with the Power Wing, and the advantages and disadvantages of whether the REO develops its own generation planning expertise or utilizes that of the Power Wing needs study. Furthermore, the scope of RE decentralized generation must be defined in terms of scale, service area and eventual role vis-a-vis the central grid.

In placing RE decentralized generation (DG) in the Distribution Wing, a procedure for budgetary allocations to cover its cost must be evolved. For economically attractive DG options (as discussed in Chapter 4), a transfer from the generation budget to the distribution budget will be necessary in order to not inhibit DG use.

It is envisaged that there would be five small units in the central organization reporting to the GM REO, each headed by a Manager at the DG/CE level responsible for the following functions:

1. Policy development, long-term plans, work programs and project preparation including coordination with provincial governments on village selection;

2. Procurement, disbursement and management of finance, accounting, budgeting, annual accounts;

3. RE networks engineering standard designs, materials and construction, and standard operation procedures; and,

4. Customer service, load promotion, load research, load forecasts, statistics, customer data base.

5. RE decentralized generation.

In each AEB a new position of Director Rural Electrification (reporting to Chairman AEB) would be created; this would be a small unit whose main functions would be to provide:

i. The local representation for the central REO functions at AEB/Circle level;

ii. On-the ground liaison support, direction, control and feedback on all REO functions; and

iii. Liaison and and negotiations with Provincial Governments on village selection which would be in accordance with the specified criteria.

While it is envisaged that the construction (and also the maintenance and operation) of the RE networks would be carried out by the Circle/Division organization, it would be desirable to provide a fully dedicated construction unit to the RE program in each AEB circle having a rural construction program. This RE construction unit would be especially trained on the new designs, materials and construction methods for the new-type RE network to be developed. In areas where decentralized generation is utilized to electrify villages, the AEB would have an SE to oversee such operations.

The new headquarters RE organization structure and the position of the additional Director RE in the AEB structure are shown in the context of the organizational diagrams in Figures 2-1 and 2-2.

2.5 Implementation of the Institutional Proposals

The current burden on the WAPDA Distribution organization is considerable and growing, the tasks associated with rapid expansion of the rural network increase this burden immensely. At the same time Distribution is undergoing a strengthening program lead through improvements in model Divisions in the AEBs. To this change and strengthening must now be added the immense task of rural electrification and the necessary changes in organization structures, systems and procedures outlined above. Under these institutional changes, the initial years of the work of the new Rural Electrification Office will be critical. In this initial period many important policy steps must be taken (e.g. setting new/alternative technical standards and equipment, beginning a monitoring and rural load research program).

As in the case of other institutional strengthening underway in Distribution, it is likely that the new WAPDA rural electrification unit will need assistance during the initial critical transitional development period. Such assistance can serve a catalytic role assisting the change and serving as a technology transfer agent (software, knowledge and approaches as well as hardware). For this, external expatriate assistance will be necessary from the start and should be maintained until the new systems are established. This assistance could be a combination of full and part time advisors. The institutions in other countries charged with rural electrification have effectively used advisors for development activities and subsequently as needed. For example, the Provincial Electricity Authority in Thailand (PEA), which is widely regarded as an effective organization retains expatriate advisors on a part-time basis and uses consultants as required. It is envisaged that during the initial period, a team of two to three full-time advisors would be required and that this team could also provide short-term consultants for special studies as required. For this assistance, the "twinning" arrangement used in some developing countries for similar projects may be relevant.

As GOP and WAPDA move to implement the new organization arrangements that are required, assistance would be sought to help develop and implement the new arrangements. This assistance would be likely to receive support from other donor agencies.

The objective of such assistance should be to develop an "indigenous capacity" in Pakistan (WAPDA) to better manage the rural electrification activities - technical, financial and administrative - and to reduce dependence on external consultants doing "one-off" studies with very limited technology transfer on project-by-project basis.

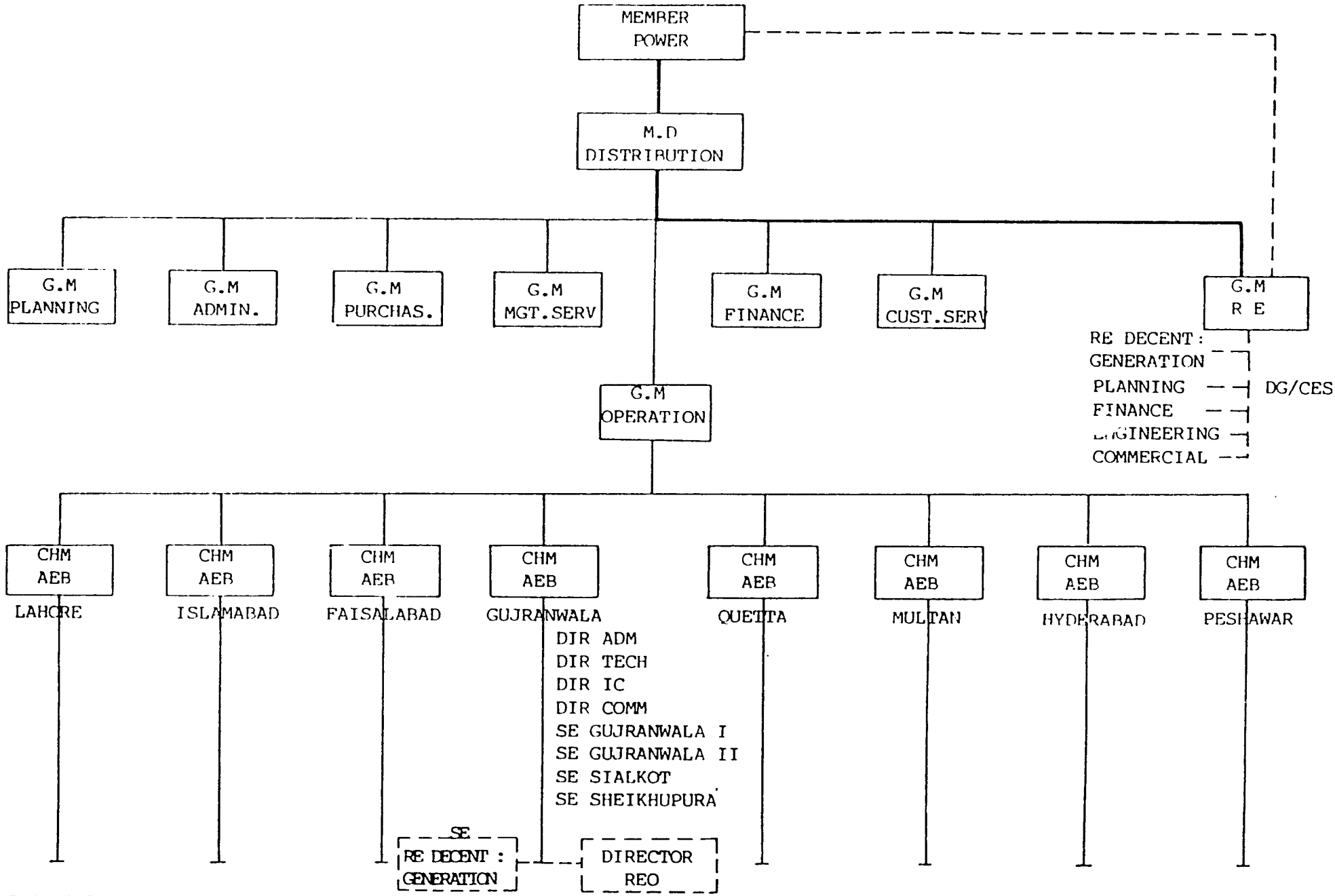

FIG. 2.1 : PROPOSED RURAL ELECTRIFICATION OFFICE - REO - WAPDA

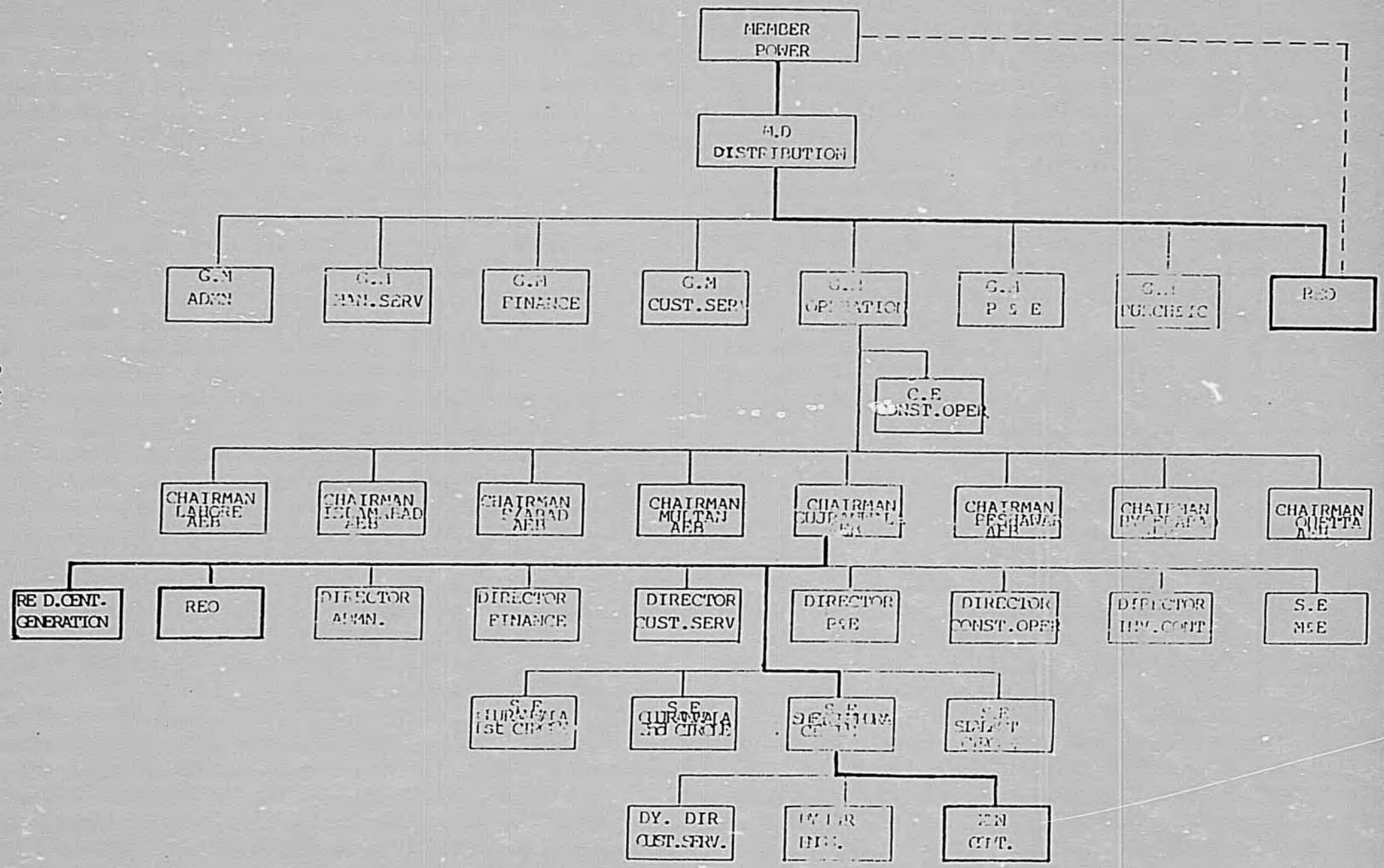

FIG. 2.2 : AREA BOARD AND CIRCLE ORGANISATION

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2.5.1 An Opportunity for Accelerated Institutional Improvement

WAPDA, with the assistance of USAID and others is implementing a broad program of institutional improvement touching all aspects of the distribution functions both at headquarters and at the AEB (initial focus on selected AEBs). An expanded RE expansion program offers a unique opportunity to accelerate the implementation of new and improved approaches and procedures. The introduction of improved institutional arrangements often requires parallel efforts of introducing the new approaches and procedures in some parts of the organization while things proceed in parallel under the former/current procedures elsewhere in the organization. Then gradually the new approaches and procedures are implemented in ever growing percentages of the organization. Much of this approach is embedded in the approved institutional improvement plan that WAPDA is implementing with USAID-PTAT assistance. Currently the initial phase of improvement is reaching to selected AEBs. An RE expansion program offers an opportunity for complementary and perhaps accelerated institutional improvement.

It is often easier to put in place improved planning, implementation and ongoing operations procedures when 'starting new"; many RE expansion areas will have such totally new characteristics. For some if not many of these new areas it may prove feasible not just to implement the new planning approaches outlined in this master plan report but also move to immediate implementations of operational changes covering many other distribution functions - meter reading, billing ongoing maintenance etc. Initially special teams perhaps consisting of AEB staff augmented by Headquarters and consultant inputs could implement the new RE areas from planning through initial operations and members of these teams could be used to disburse this experience and know-how both elsewhere in the particular AEB and to other AEBs.

2.6 Use of Cooperatives and Private Companies

Rural electrification is very much a social program; the fiscal dimensions of this are examined in the next chapter of this plan. However it is useful to note that the social nature of rural electrification is another of the characteristics (along with the technical and other differences) which make rural electrification "distinct" from urban electrification. It can have a separate culture because the involvement of the community in the social service may be essential. In many countries this is done by organizing local committees to carry out pre-canvass in their villages and again maximize local acceptances to improve cost/revenue returns and move their village higher up on the pecking order for selection to be electrified.

2.6.1 Rural Cooperatives

From such local community involvement, it is but a short step to a Rural Cooperative where the village or community says they will take group supply from the power authority and provide their own distribution and collect money from individual consumers to pay the power authority (or pay for their own diesel) and to set aside funds to pay operating and maintenance charges on their own network. In some countries, the cooperatives are engaged in the construction of small hydro plants. In a few countries the cooperative structure is well developed with cooperatives encompassing multiple communities and much if not all of the rural electrification systems.

The use of cooperatives for RE can lead to significant improvements in the costs of construction, maintenance and operation and also in the collection of revenue. The realization of these benefits in countries such as the Philippines and Bangladesh have been less than what was originally envisaged, but there is sufficient experience available from such countries to indicate that the use of cooperatives in Pakistan under certain conditions could be desirable. One of the first tasks of the new REO organization, working with representatives of the Federal and Provincial Governments, would be:

i. to establish the arrangements and conditions under which cooperatives could be used in Pakistan; and,

ii. to implement pilot projects to validate the arrangements.

The new WAPDA REO along with representatives of the Federal and Provincial Governments would review studies and evaluations of cooperative experience in other countries and arrange to visit those countries. These visits would be to examine first hand the arrangements used and to analyze causes for successes and failures, and then to design systems appropriate to Pakistan, which would eliminate the major difficulties encountered elsewhere.

2.6.2 Private Companies

In various situations in many countries, in addition to isolated systems operated by government or government utilities, small private rural power systems evolve in response to a need with or without government assistance. In many countries such systems predated the expansion of the grid. Such separately operated (private or government) systems should continue to be an option especially in areas remote from the grid as these are likely to be more economic than if operated by WAPDA.

Thus in addition to using cooperatives, consideration will also be given to the use of private companies in rural electrification. Such companies can be used for:

i. Provision of the generation only, serving cooperatives who distribute only, and/or providing decentralized generation for the WAPDA operated rural distribution systems;

ii. Provision of self-contained supply facilities including generation and distribution in remote areas; and,

iii. Provision of distribution facilities and services (taking bulk supply from the grid) to supply groups of contiguous customers.

Each of these undertakings would be required to be licensed by the regulatory authorities and the terms, durations, conditions, and tariffs (or subsidies) permissible clearly specified. As outlined above, one of the priority tasks of the new REO organization will be to develop policies, plans and procedures on the scope of the involvement and participation of cooperatives and private companies in RE. The assistance of external advisors will be sought in this task.

Future evolution of the institutions involved in rural electrification could include both cooperatives and private involvement (possibly with government financial and technical assistance). Such evolution will be compatible with the institutional changes outlined above, but any role for cooperative or private systems would have to come under a central regulatory and financing authority. This authority can be located as outlined in the discussions above on the various options and in the longer-term this would be the function of the National Distribution Authority.

2.7 Summary

The Government of Pakistan needs to approve and implement new institutional arrangements, organizational structures, systems and procedures without delay. WAPDA presently acts as the implementing agency for Government on the present RE program and it is proposed that WAPDA continue to implement the RE program with the improved organization structures.

A new Rural Electrification Office (REO) would be established under a new General Manager reporting administratively to the Managing Director Distribution and also functionally to the Member Power on policy, strategic plans, financing and area selection. The feasibility of using cooperatives and/or private companies in the rural program would be considered from the outset. The REO would be small in size but very effective and influential and be fully discrete and self-contained on all the accounting, economic and technical functions. It would work with and through the total WAPDA organization on other functions. Ongoing construction would be carried out in the AEBs. A new position of Director of Rural Electrification would be created in each AEB and an Executive Engineer (XEN) construction unit would be fully dedicated to the rural program.

These proposals for institutional change will complement the ongoing WAPDA USAID program and indeed will assist in accelerating the various institutional improvements proposed for the distribution function. In the longer-term the institutional changes proposed here can facilitate the possible eventual establishment of a separate National Distribution Authority with a number of decentralized Distribution Companies.

Pilot programs for rural cooperatives and private companies should be undertaken. In other countries, such alternatives has lead to savings in the construction, operation and maintenance of electrical supply and better connections. Cooperatives could be used for distribution and possibly decentralized generation. Private companies could be used for generation, distribution or both jointly. The new REO along with the Federal and Provincial governments should review the experience in other developing countries and develop initial guidelines, tariffs and regulations which would be tested in the pilot programs. Such guidelines must be designed with care to avoid the problems encountered in other countries.

Chapter 3

Benefits, Costs and Revenues: Implications of Current Policies and Needed Changes

3.1 Introduction and A Perspective on Benefits, Costs and Revenues

In Pakistan, as in most developing countries and many industrial countries, rural electrification is a program aimed at socio-economic development. Rural electrification investments are usually not financially viable (financial revenues covering all financial recurrent and replacement costs) at the start. And in many cases RE investment can never become viable unless capital grants are provided at the outset. However, such investments may be viable based on broader economic or socio-economic criteria. In Pakistan, the Government's objectives relevant to rural electrification investment (and operations) include more than financial and economic efficiency but also include equity and rural development. An important part of the rural electrification planning process must be to examine rural electrification investment (and operations) policies in light of these objectives- financial, economic and socio-economic to ensure that resources are used effectively. This examination starts in this Chapter of the master plan and inferences regarding policy changes needed are outlined.

In Pakistan, and other countries, whether revenue from rural electrification projects can recover the operating costs and all or part of the capital costs is a function of not just the costs. The degree of cost recovery also depends on the tariffs and collection efficiency as well as the consumers capability to pay these tariffs. In this chapter estimates of rural electrification revenues are compared, for classes of consumers, with both capital and recurrent costs and policy inferences are made. If a rural electrification investment is financially viable it is reasonable to expect the power utility to make the investment. However, no power utility can carry, on a continuing basis, the cost of investments which are not financially viable. Thus in many countries, Pakistan included, most rural electrification investments are usually capital grant-funded by Governments. In the case of such grant funding, if rural revenues still fall short of remaining financial costs, either tariffs must change or annual operations subsidies must be provided, assuming these projects are viable on economic or socio-economic bases and are executed in a cost effective fashion. In this chapter various implications (such as the implicit subsidies) under current policies are examined for classes of consumers and villages, and inferences are made regarding needed policy changes.

3.1.1 Polices Examined in This Chapter

Analysis of the benefits, costs and revenues provides a basis for examining the many different interrelated policy components that constitute the overall rural electrification policy. The analysis of benefits, costs and revenues presented here builds on the analysis of some of the institutional,

technical, financial and economic issues presented in the previous chapter; and also integrates some information from the detailed analysis of other chapters. The analysis of benefits, costs and revenues along with other information discussed, supports inferences regarding the following policy components:

1. policies regarding intensification (backfill in existing villages) versus extending the system to new villages/settlements

2. consumer connection policy;

3. tariff (and subsidies) policy;

4. village/settlement selection policy;

5. technical standards and supply alternatives; and,

6. monitoring and planning support policy.

The process of analysis supporting inferences regarding these policies is one of first looking at the benefits, costs and revenues in the context of both the supplier (WAPDA) and its representative electricity users. The rural user categories examined include tubewell customers, households, industrial and commercial consumers. The analysis also examines the benefits, costs and revenues accounted on the overall village/settlement basis in which the villages/settlements consists of illustrative combinations of different classes of customers.

The analysis is done (and presented) in both financial and economic terms and the inferences regarding policy draw on both the financial and economic conclusions of the analysis. Summary results of the analysis are presented below, but first it is useful to present some perspectives on benefits, costs and revenues and the interrelated nature of the policy components.

3.1.2 The Interrelated Nature of Technical, Tariff and Connection Policies

The implications of different aspects of rural electrification policy are very interrelated and should be considered, to the extent feasible, in an integrated systems fashion. Obviously, financial viability is dependent on the costs and the tariff policies as well as other factors, but costs are in turn dependent on questions of technical standards and equipment. Electricity use (demand) and hence both revenues and benefits are a function of availability of electricity and the total electricity price. Availability of electricity is a function of both consumer connection and village/settlement selection policies and the total price incurred by the consumer is also dependent on the consumer connection policies. Other linkages between technical standards, tariffs and connection policies can be cited.

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The terms of reference (TOR) for the master plan study cited the various policy issues to be covered by the plan in a series of items (see Appendix K) but the wording of these TOR items did not reflect the interrelated nature of the policy issues. However, the master plan team has attempted to capture the interrelated aspects of technical standards, tariffs and connection policies in the case analysis approach being used to examine the policies and to suggest changes. And hence much of the reporting on these policy issues, particularly that covered in this chapter of the strategic master plan, discusses particular policies in the broader context of the characteristics of other policies.

3.1.3 Benefits and Costs in the Context of The Former Prime Minister's Program

The former Prime Minister's program for rural electrification had set a goal of electrifying ninety percent of the census villages. The budgetary requirements of this undertaking are large. Recent estimates were Rs 17,800 million (Ref 27 and 72). However, these estimates did not include the fact that most villages have several settlements; and for the rural population to have access to electricity, these settlements need electrification. The number of settlements, estimated to be many more than 100,000, is much larger than the number of census villages, numbered at some 46,000. The definitions of rural electrification presented in Chapter 1 above suggests that it is necessary to include these settlements.

Meeting a ninety percent target based on settlements will require a budget of staggering size. At current, or even significantly increased levels of expenditures, meeting such targets will take quite a number of years. If all the target were achievable in a few years the planning of the time pattern of expenditure would not be so important as the difference between a well planned program and a not so well planned program is only the relative time pattern of a few years and the potential costs of such inefficiencies are not then too large. But in a program that will take some years, as must be the case if ninety percent of the settlements are to be electrified then a well planned program is critical. Electrifying villages in some relationship to highest benefits/lowest costs means that capital will be effectively utilized from the start; failure to do so can mean that capital is wasted for years. And in an environment of scarce resources, which Pakistan is facing, capital must be used effectively. Hence, as discussed below, knowing that costs and benefits are crucial, these costs and benefits should be the basis for a well planned program.

3.1.4 Knowing the Costs and Benefits of A Rural Electrification Investment

A well managed utility should know the implications of the financial costs and revenues associated with any investment, and using these financial costs and revenues analyze the investment's financial viability. This should be done for all investments, for investments in the rural components of the system or investments elsewhere in the system.

In WAPDA, such analysis is routinely done for major investments such as generation and transmission expansion and to a lesser extent is used as part of the preparatory analysis for distribution rehabilitation investments being undertaken through USAID financing. Such cost and revenue analysis, even in its simplest form, has not been generally undertaken for ongoing rural system investments except as an adjunct to special preparatory work for some externally financed project. Such analysis must become routinely part of rural electrification planning and preparation as it is part of standard good utility management practice. The introduction of such analysis as part of rural electrification planning is consistent with evolving Government policy as articulated in the new Plan which includes moving WAPDA to more commercial standards of operation. Furthermore, the new work order system developed by PTAT for distribution work includes the estimation of the economic internal rate of return.

Techniques to perform the needed, technical, financial cost and revenue analysis can be made simple and straightforward, and introduced at the field level with some minimal amount of training. Field staff already deal with the technical and costs matters, and will readily understand the concepts of the revenues associated with costs. The necessary analysis can be done in the field (WAPDA/AEBs) based on simple procedure manuals developed by the new Rural Electrification Office (REO) described above in Chapter 2. Indicative examples of such analysis are shown in this strategic master plan for rural electrification in Chapter 4.

Financial cost and revenue analyses, alone are not insufficient to judge rural electrification investments and policies since, as indicated above, the criteria for examining rural electrification investments and policies must include broader economic and socio-economic criteria. Utilizing such criteria it should be possible to place all rural electrification investments in one of three categories:

Category 1: Projects which are financially viable on their own (there will be very few in Pakistan) and which the utility could (and should) finance on its own;

Category 2: Projects which are economically but not financially viable; Government should finance the most viable on economic efficiency grounds; and,

Category 3: Projects which are not even economically viable; Government may finance some of these based on equity or other social criteria.

The analysis necessary to categorize rural electrification investments as outlined immediately above goes beyond simple financial analysis and requires economic and socio-economic expertise. Such expertise will in the future be found in the new WAPDA headquarters REO. It will be this unit's responsibility, building from the work done in developing this plan to:

i. organize and supervise necessary load research, monitoring and evaluation studies to allow revised estimates of planning parameters; and,

ii. prepare and periodically revise detail planning procedures/instructions for the AEBs to use in the RE investment analysis.

The initial applications of the economic and socio-economic approaches to estimate the necessary planning parameters and develop the planning procedures was undertaken as part of the preparation of this strategic master plan. These approaches and application procedures are presented in this report and its appendices. Also an initial outline of the necessary further studies, ongoing load research, monitoring and evaluation is presented in Chapter 6 of this report.

The initiation report for this master plan (Ref 30) discusses the major differences between economic and financial analysis. In brief, the financial analysis uses market place prices faced by customers and the utility. These financial prices include taxes and duties, and reflect those effects that restrict prices such as regulatory policies and limited competition. On the other hand, economic analysis attempts to examine the benefits and costs from "society's" point of view where the goal is the optimal or most efficient use of the country's resources. A major aspect of economic analysis is the adjustment of project financial costs by using what are called "shadow prices" or conversion factors. For example, costs are adjusted to eliminate taxes and duties because from an economic viewpoint taxes are not a cost to society overall but are only transfers of money from one to another part of society. This case is particularly relevant to the cost of RE equipment.

The analysis in this study is based on the approach that, for government policy making, decisions should be made on the basis of economic analysis not financial analysis, whereas financial analysis is relevant to understanding the behavior and needs of the utility and customers. In addition, recognizing that government policy must also consider broader issues than just economics, socio-economic analysis provides a means to incorporate social and political goals in this quantitative analysis. One approach to socio-economic analysis uses what are called "social weights" to give more or less value to different benefits and costs. Even when socio-economic analysis is used to justify a project, the economic analysis is needed to understand the benefits and costs of the project to the country.

3.2 RE Revenues and Electricity Supply Costs

The RE revenues considered from the utility's perspective are both the tariff revenues and the connection charges the customer pays to the utility. From the customers perspective there are payments to the utility, to a contractor for wiring and there maybe additional "unofficial" charges paid but not received by the utility.

3.2.1 Electricity Supply Costs

There are different components of the costs of providing electricity to rural consumers; these costs are presented in some detail in Chapter 5 below and in supporting Appendices. For the purposes of this discussion, it is useful to distinguish between costs in the following categories:

1. Generation and Transmission (G&T) Costs - these are the costs of electricity (capacity and energy) entering the rural system;

2. Rural Electrification Distribution Cost - these costs cover bringing electricity from the transmission network to the customer connection and consist of two parts:

   a. Area Distribution which will range from some additional transmission for rural areas alone, some grid substations, but mainly the 11 kv and 33 kv lines to villages.

   b. Village/Settlement Distribution which covers low and high tension lines and transformers within the village.

3. Customer Connection Costs - these costs cover service drops, meters, and, when done by the utility, customer internal wiring and end use equipment such as lights for households etc.

4. Customer Internal Costs - these costs cover the wiring in the customers' premises and end use equipment (generally paid by the customer).

The latter three cost categories cover the RE system. For each of these cost categories, as discussed below, there are (i) capital or capacity costs and (ii) recurrent costs covering operating, maintenance, fuel and other annual or variable costs.

The cost estimation for this rural electrification study has been dealt with in a number of ways depending on the level of analysis. This section and supporting Appendices B and J present an overview of the approaches and the results. One of the most important distinctions is between the technical and economic analyses. The technical work presented in Chapter 5 is based on detailed studies of the current prices of items, the bill of materials needed, and the costs of installation. The economic analyses use more aggregate cost factors such as average costs per kw of village distribution or per type of customer service connection. The aggregate costs in the economic analyses are coordinated with the results of the technical analyses and sensitivity analysis is performed to incorporate the results of the technical work. Such sensitivity analysis is also necessary to cover changes in costs which arise because the economic and technical analyses were performed simultaneously and some economic work had to be performed before all technical analyses were completed.

The cost analyses incorporated in the economic analyses consider a number of view points:

1. Load factors are very low in rural areas; and since electricity supply is very capital equipment intensive, the total supply cost is very dependent on load factors. Load factors are interdependent with utilization levels and peak coincidence between different customer types, villages/settlements, feeders, districts, and urban-rural loads. Rural load factors vary from 10 to 30 percent, whereas the overall national load factor is about 60 percent. Capital related charges (costs) for both the RE and G&T parts of the supply system form the majority of total costs. RE capital charges are about 50 to 67 percent of total RE costs. The G&T capital charges form a similar and sometimes higher percentage of total G&T costs. The cost analysis explicitly captures the sensitivity of total costs to load factors by using capital (capacity) and recurrent (energy) charges and not average total costs.

2. RE costs are viewed from an area perspective such that the expansion process of RE is the implementation of a repeating pattern of distribution and some transmission. Therefore, the costs are estimated based on models of an illustrative unit of RE which could either be a 400 sq km area served by a 132/11 kv grid substation or a 2500 sq km area served by a 132/33 kv grid substation. Because of the very large economies of scale of transmission, the evaluation of expansion of the RE system is mostly a function of load spatial density rather than distance from the existing grid.

3. Both economic and financial costs are examined. For the RE costs, the major differences are the duties and taxes in the financial costs, since there is no shadow premium for foreign exchange and the shadow price for unskilled labor is close to the financial one. As a result, RE economic costs are estimated to be 70 percent of financial costs. The other major difference is the choice of discount rate: (i) for financial analysis - 15% and (ii) for economic analysis - 10%. For generation and transmission (G&T) from the central grid, the economic costs are based on expansion planning analysis and the financial costs are based on historical costs. As presented below, economic G&T costs are much higher than financial costs.

4. Two sets of overall costs for RE distribution are considered: (i) current costs based on present day technical and system specifications and (ii) possible low-cost ones based on new alterative specifications. The low cost options are based on the analysis presented in Chapter 5.

3.2.2 Summary of Electricity Supply Costs

Table 3.4-5 presented below indicates the unit supply costs for an illustrative main village/settlement. The underlying bases for many of these costs are presented in Appendices B and J.

Generation, Transmission and RE Costs

An approximate breakdown of costs between generation and transmission (G&T) and RE, and between capacity and recurrent costs is as follows:

Financial Analysis

	Totals (Rs/kwh)	Total (% of total cost)		Capacity	Recurrent
Generation & Transmission	0.61	32	=	19	13
Rural Electrification	1.31	68	=	51	17
Total	1.92	100	=	70	30

Economic Analysis

	Totals (Rs/kwh)	Total (% of total cost)		Capacity	Recurrent
Generation & Transmission	2.09	75	=	53	22
Rural Electrification	0.69	25	=	17	8
Total	2.78	100	=	70	30

The economic costs of power generation and transmission are much higher than financial costs. This problem is being addressed by the current plan to work towards long-run marginal cost (LRMC) pricing of electricity. Economic G&T costs are much larger than the RE distribution costs. The high G&T costs are a function of the low load factor of rural demands such that rural G&T costs are more than double average system G&T costs. Furthermore, Pakistan's LRMC G&T costs are high partially because marginal power generation in the future is based on imported oil and coal and high cost hydro. This cost of G&T together with the low rural load factors is one of the major reasons why RE is difficult to justify economically. One of the other major reasons, and one which can be addressed in subsequent phases of RE work, is the low estimates of RE benefits. This is partially due to the incomplete information base; more information will likely lead to higher benefit estimations.

The economic cost/kwh of G&T is estimated to vary from 1.8 to 4.2 Rs as the load factor declines from 30 to 10 percent. At the national system load factor of about 64 percent, the G&T cost is about 1.2 Rs/kwh. These results indicate the sensitivity of total costs to load factor, and this is due to the high estimated capital intensity of power production. The economic costs estimated by the study team, as explained in Appendix B, are capital costs of 30,000 Rs/kw-demanded and recurrent costs of about 0.6 Rs/kwh-delivered. Follow-on RE planning work must refine these cost estimates. In the economic analysis presented below, the sensitivity of the results to economic G&T costs which are less capital intensive (such as capital costs of 20,000 Rs/kw-demanded and recurrent costs of 0.75 Rs/kwh) are considered.

Financial and economic costs of G&T can differ for several reasons. One is the differences in the underlying costs of capital, fuel and other inputs between what are considered financial and economic prices. Another is a difference in the perspective of the analysis. Economic analysis, when correctly done, is forward looking in that it examines the cost of meeting future demands for electricity. On the other hand, the approaches for financial analysis vary with some being forward looking (as in the economic analysis but using financial prices) and others being based on historical costs for existing G&T). Analysis based on historical costs generally lead to lower costs than analysis based on future costs as future costs are higher due to the effects of inflation, increasing average costs (despite economies of scale, higher cost hydro or fuels are needed), and increasing demand. Some of these account for the large differences between financial and economic costs of G&T indicated above.

As explained in Appendix B, the financial costs are based on NAPDA Power Statistics (Ref 5), which are based on historical costs. The economic costs are based primarily on a UNDP/WB power system planning exercise (Ref 175) which does expansion planning over a 20 year horizon. The economic costs are, therefore, based on forward-looking costs whereas the financial ones on historical costs.

It must be noted that the G&T costs used in the plan are very approximate estimates. Unfortunately, recent estimates (especially of the long-run marginal cost) are not available, and such work is beyond the scope of this plan. The analysis in this plan must be re-examined when new cost estimates are developed such as by the pending ADB tariff study. It appears that the general conclusions presented in this chapter are not rather robust in that they do not change even with substantially different estimates of G&T costs.

Breakdown of RE Costs

The breakdown of RE costs based on their net present value of both capital and O&M costs over a 20 year period (see Appendix G) for an illustrative new village/settlement is as follows:

	Percent of Total
Area Distribution	40 to 55 %
Village/Settlement Distribution	20 to 30 %
Customer Connection	20 to 35 %

This breakdown is a function of a number of conditions. For example the area distribution costs for a village are dependent on both the distance from other villages and from the grid. Both the area and village/settlement distribution relative costs vary with the intensity of the electrification: the more spatially dense the electrified settlements and villages, the lower the area cost. Furthermore, the higher the penetration rates and the denser the village, the lower the settlement distribution cost. The customer

connection costs share will increase significantly as penetration rates increase and/or as tubewell connections increase. The above cost breakdown indicates a particularly large share for customer connection because these percentages are based on a high level of customer penetration. If only the capital costs for the first year were examined, the connection costs would be a much smaller percentage and (under existing customer connection policies) the distribution costs a higher percentage.

3.3 Economic Benefits and Costs Considered

Financial viability is not the only criterion relevant to examining rural electrification policies and investments. In fact while the financial viability is very relevant from the utility (WAPDA) perspective, other broader criteria must be incorporated. Following the ideas outlined in the Master Plan Initiation Report (Ref 30) the other criteria to be considered are:

1. economic viability as indicated by an appropriate comparison between economic benefits and costs (such as the benefit to cost ratio);

2. social benefit cost criteria, through which the projects inputs and/or outputs are adjusted to reflect impacts on village and regional income distributions.

3. complementary investment criteria (rural electrification as a complement to other rural development investments); and

4. other criteria such as environmental and administrative concerns.

3.3.1 The Use of Economic Viability and Other Criteria

The Master Plan Initiation Report (Ref 30) suggests that economic viability criteria should be central to rural electrification planning; and economic criteria play a central role in this plan.

The other criteria are also incorporated in the development of this plan. The equity criterion is introduced in multiple ways:

i. equity among income groups is considered by qualitative consideration of social weights as discussed below;
ii. incorporation of targets for household connections in electrified villages and consideration of new connection/financing mechanisms; and
iii. regional equity is considered in the suggested algorithms for budgetary allocation between provinces and within provinces.

The complementary investment criterion is considered in only a qualitative fashion due to information constraints highlighted below. However, it is suggested in Chapter 4) that the complementary criterion, as measured by development potential, be incorporated in the algorithm for allocating RE investment budgets among districts within a province. Environmental criteria are not considered and administrative criteria are implicitly incorporated into the design of the planning process so as to have procedures that are practical and replicable (for future extension and revision by the new WAPDA REO and the AEBs).

The incorporation of these broader criteria starts by building from the financial analysis. This is the procedure done in the preparation of this plan and with modifications/revisions it should be followed by the AEB units implementing RE planning with guidance from the new WAPDA REO. From the perspective of evaluating rural electrification investments, there are at least three distinct differences between financial viability and economic viability criteria. These are:

1. the use of economic prices rather than financial prices;

2. the incorporation of direct benefits, in particular consumer surplus; and

3. the incorporation of indirect benefits (such as those resulting from local manufacture of project inputs)*.

3.3.2 Self Contained versus Complementary Investment Benefits

How the benefits are defined and estimated depends upon whether one views rural electrification as a complementary rural development investment or as a self-contained directly productive investment. Unfortunately RE has attributes of both. The analysis of RE as a self-contained productive project is limited to the direct and indirect benefits and costs accrued, but without explicit "internalization" of complementary inputs or other forward and backward linkages. This has been the traditional approach to evaluating RE. Economic justification for purely complementary projects is, however, very difficult to characterize without extensive ex-post evaluation of complementary investment projects. Often, in the absence of such extensive evaluations, the approach is to simply attribute some fraction of future development benefits to the RE part of the package of rural development investments. It is frequently assumed that RE investments are "necessary" for development and are executed without specific economic justification. Because of information limitations (see below), the approach that is used here is to first estimate the benefits of RE viewed as a self contained investment, and then include judgements of as many of the benefits of the complementary investment aspect that might be justifiable (and measurable).

As detailed in the Appendices, the economic benefit estimates explicitly incorporate economic prices and include consumer surplus estimates. The limitations, primarily due to information constraints, which need to be pointed out here (and are discussed further in Chapter 6 and in Appendix C), are as follows:

*If the economic prices used are not just judgemental estimates, and are used for all inputs and outputs, then these price estimates can reflect such indirect benefits as local manufacture. However, even if the economic prices are correct there can be indirect benefits which are not quantifiable or take considerable time to materialize.

i. Prior RE studies used inconsistent and/or incorrect estimates of rural kerosene use and hence resulted in serious overestimates of some RE benefits (kerosene substitution); this has limited the availability of consistent information for the new estimates used herein;

ii. in Pakistan, no ex-post detailed impact studies are available comparing electrified and non electrified villages/settlements and consumer groups, and hence no information is available on which to base quantitative estimates of indirect benefits; and,

iii. little detailed intersectoral integrated rural development analysis has been conducted (a-priori or ex-post) and hence no information on which to base quantitative estimates of complementary investment benefits is available.

Despite these constraints, considerable effort was made at parameter estimation for the economic benefit/cost analysis, which proved useful in examining policy and investment options. Some of the results and inferences of this analysis are presented in the following subsections. Because of the data limitations, the exact figure presented should be viewed as only indicative of actual values; nevertheless, the general conclusions are quite sound. More importantly, the data used in this type of analyses should be viewed as the outcome of on-going examination of the effects of RE. In all of the cases the summary economic and financial analysis results are presented in the tables shown below. In each of the tables referred to in the economic discussion below, the electric system costs are in economic prices, the economic benefits presented are based only on estimates of direct benefits including consumer surplus. Qualitative discussion of other indirect and complementary investment benefits are made in the comments and inferences as are comments on the implications of using social-economic weights to reflect equity objectives. The figures for economic costs and benefits are presented on a per kwh basis.

3.4 Economic and Financial Analysis and Inferences for Policy

For illustrative consumers and existing tariff policies, in the financial analysis it is important to compare the costs borne by the supplier (WAPDA) with revenues and also the costs and financial savings/benefits to the consumer. Then it is necessary to extend this examination to look at economic benefits and costs from society's perspective. From these examinations and comparisons and similar ones made looking at villages as a whole, it is possible to draw inferences regarding existing policies. It should be noted that the illustrative costs presented below attempt to portray most common situations for different customer types. Obviously, there are many exceptions due to regional, provincial or other differences. In some cases, sensitivity analysis is performed to examine the implications of different situations. If exceptions are significant, they will need to be examined as part of the continual process of policy change and modification.

In the following discussion, the RE costs presented in the tables, unless otherwise noted, are based on current technical practice. However, based on the case analysis summarized in Chapter 5, the implications of possible significant RE cost reductions are discussed, in the following text. Financial costs and revenues are examined first and inferences are made. The examination is then widened to include economic benefits and costs and additional inferences are made.

Gross benefits, as presented below, are measures of the total willingness to pay by customers for the electricity service from the utility. It should be noted that the direct gross benefits estimates made in this study in most cases underestimate the actual benefits from RE. The demonstration of substantial RE benefits requires extensive information collection and analysis on an ongoing basis. Such information is, unfortunately, not yet available in Pakistan; and as discussed in Chapter 6, it will be a focus of the implementation of the RE plan. Another factor leading to the probable underestimation of benefits is the historically low electricity tariff which likely hides the fact that customers are willing to pay much higher amounts for electricity. As a result, the following economic and financial analyses are conservative in their benefits estimations. Since the major thrust of this plan is the rationalization of the RE process and this underestimation is probably true for nearly all customers, the biases introduced are not severe. The selection processes suggested in this study are designed to be updated as more information becomes available.

3.4.1 Financial Costs and Revenues and Economic Benefits and Costs - Cases of Illustrative Tubewell Users

The columns labelled financial analysis of Table 3.4-1 present the financial income flows for an illustrative tubewell user. The financial flows are shown for both the utility (WAPDA) and the customer. The figures are presented on a per kwh basis. The revenue figures for the base case are for the Tariff Category D, the non-flat rate tariff. For the high utilization case, the flat tariff D-1 was used. For a 10 kw load, the flat tariff becomes less expensive at pumping levels above about 1300 hours per year. The costs assume current pumping practice which includes significant pumping during the peak period of demand. The results in this table and the details of this and other tubewell user cases analyses are presented in Appendix E. The results shown in the financial analysis columns of Table 3.4-1 allow the following comments and inferences:

i. It is clear that while the use of an electric tubewell (as opposed to diesel) is very financially attractive for the user, WAPDA incurs a financial loss of about 1.5 Rs/kwh in the base case;

ii. The base case tariff revenues per kwh (0.30) exceed total recurrent costs (0.68) and so WAPDA current account is solvent for such customers; but after covering recurrent costs there is only enough to cover a small fraction of the fixed capacity costs. Hence, even if the RE distribution and connection capital costs are fully subsidized by a capital grant, there is still a financial loss to WAPDA.

TABLE 3.4-1: ILLUSTRATIVE IRRIGATION TUBEWELL CUSTOMER ANALYSIS

BASE CASE: electric tubewell of 8.3 KW operating 1000 hours/yr in base case (Tariff D)
high utilization case operates for 2000 hours/year (Tariff D-1)
electric motor efficiency of 70% versus diesel engine efficiency of 17.5%
with peak coincidence factor of 65% at generation

	Financial Analysis				Economic Analysis	
	Utility		Customer		Society	
	Base	High Util	Base	High Util	Base	High Util
A. REVENUES						
1. Tariff (Punjab and Sind)	0.80	0.51	n.a.	n.a.	n.a.	n.a.
2. Connection Charges	0.19	0.10	n.a.	n.a.	n.a.	n.a.
3. Gross Benefits (a)	n.a.	n.a.	2.60	2.55	2.02	2.00
Totals	0.99	0.61	2.60	2.55	2.02	2.00
B. TOTAL SUPPLY COSTS (b)						
Recurrent (Variable) Costs						
1. Generation/Transmission	0.25	0.25	n.a.	n.a.	0.61	0.61
2. RE Distribution	0.19	0.10	n.a.	n.a.	0.14	0.07
3. Connection	0.24	0.12	n.a.	n.a.	0.17	0.08
4. Tariff	n.a.	n.a.	0.80	0.51	n.a.	n.a.
Subtotals	0.68	0.47	0.80	0.51	0.92	0.76
Fixed (Capacity) Costs						
1. Generation/Transmission	0.51	0.26	n.a.	n.a.	1.95	0.98
2. RE Distribution	0.60	0.30	n.a.	n.a.	0.29	0.15
3. Connection	0.74	0.37	0.38	0.19	0.39	0.18
Subtotals	1.85	0.93	0.38	0.19	2.63	1.31
Totals	2.53	1.40	1.18	0.70	3.55	2.07
C. NET INCOME / BENEFITS	-1.54	-0.79	1.42	1.85	-1.53	-0.07

NOTES: n.a. - not applicable

a. Average of low speed diesel retrofit and high speed diesel new installations.

b. Financial generation and transmission costs based on capital costs of 5,200 Rs/kw (at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kw (at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

The recurrent costs of G&T include system losses of about 20 percent. 32306

iii. From WAPDA's perspective, the picture improves for the high utilization case but not sufficiently; substantial financial losses are still incurred.

iv. Such a policy is not viable over any long term period as it implies that other large portions of the system capital costs are not being covered either by the customer through tariffs or by Government grants to WAPDA in excess of RE capital costs.

The column labelled economic analysis of Table 3.4-1 presents the economic cost and benefit flows from society's perspective in the case of illustrative tubewell users. The economic benefits are based on the net savings (in comparison to diesel pumping) measured in economic prices. Details are discussed in Appendix E. The economic analysis results lead to the following comments and inferences:

i. In marked contrast to the financial analysis, it is beneficial financially for the user but substantially uneconomic for society under the base case;

ii. Economic benefits, in the base case, cover recurrent economic costs plus almost half of fixed (capacity) costs. There is a large economic shortfall from the 2.60 Rs/kwh fixed cost, of which the majority is system generation and transmission costs.

iii. Much of the uneconomic results are due to the low load factor. Only under the high utilization case of pumping 2000 hrs per year does pumping begin to be economic. With the addition of either load management <u>or</u> RE cost reductions the high utilization case is nearly economic.

iv. The large cost reductions which may be possible for tubewell connections (perhaps up to 50 percent) and decreases in area distribution costs (on the order of 30 percent), as outlined in Chapter 5, will not make the base case irrigation pumping economic even if pumping is load managed. Only increases in pumping load factor together with load management and/or RE cost reduction can make pumping economic. Even using lower (about 20%) estimates of the economic cost of generation and transmission do not alter this result.

v. Current policy of encouraging electric tubewells, to the extent that the average operating level is only about 1000 hours per year, appears to be a very costly and inefficient means in economic terms to assist agricultural producers and can not be justified on equity criteria. Other alternatives to aid pump irrigation could be more economic; for example, an increased program to promote diesel tubewells and a complementary program for efficient selection and use of tubewell equipment. The use of power factor correction capacitors which could significantly reduce capacity and network costs, together with the other improvements mentioned above, can enhance the economic position of electric tubewells.

vi. To avoid such economic losses with current customers it will be necessary to establish financial tariffs which relate to economic costs and which provide incentives (savings) for off-peak pumping and improved power factors, and at the same time constrain on-peak pumping. Such tariffs will produce financial costs for the user which are higher than the diesel option for low load factors, in which case some users may switch to diesel; while some new users will pick diesel which then have lower financial and economic costs. Some users may stay with electricity under such tariffs if there are other convenience or other preferences not captured in the above comparative analysis. Until such tariffs are in place, at a minimum, all pumping should be load managed to restrict peak period pumping.

The above comments, based on the financial and economic analysis, question the wisdom of continuing tubewell electrification under existing policies. On the assumption of continued tubewell electrification, these comments also indicate the importance of tubewell tariff reform and load management. These are discussed in Section 3.6.1 following the analysis of tubewell users' benefits and capacity to pay (Section 3.5.1).

The move to tariffs based on economic costs will likely lead to proportionately higher costs in Baluchistan and NWFP, where pumping heads seem much higher and the demand more dispersed. It is necessary to study whether the possible cost increases are substantial in the context of total farming costs, and whether subsidizing electricity is the best way to assist the agricultural development in these provinces.

3.4.2 Financial Costs and Revenues and Economic Benefits and Costs - Cases of Illustrative Household Users

The details of the household user case analysis are shown in Appendices C and D. The results discussed in this subsection are drawn from these case analyses. Tables 3.4-2(A to C) present some results of the case analyses for illustrative high, middle and low income household users. Again the columns of the financial analysis present results from the perspective of the utility and of the customer. As in the tubewell user discussion, the figures are presented on a per kwh basis. The revenue figures are for Tariff category A-1. The financial results shown in A, B and C versions of Table 3.4-2 and other results allow the following comments and inferences:

i. For all rural household income groups, WAPDA incurs a financial loss, but the per kwh loss is lower for all household cases than for tubewells;

ii. Only revenues from the high income group tariffs cover the recurrent costs but even for this group there is little remaining to cover fixed capacity costs;

TABLE 3.4-2A: ILLUSTRATIVE HOUSEHOLD (High Income) CUSTOMER ANALYSIS

BASE CASE: high income (about 10% of rural population)
annual electricity use of 1800 kwh with 1.0 kw peak
with peak coincidence factor of 65% at generation

	Financial Analysis		Economic Analysis
	Utility	Customer	Society
A. REVENUES			
1. Tariff A-1	0.44	n.a.	n.a.
2. Connection Charges	0.10	n.a.	n.a.
3. Gross Benefits	n.a.	1.60	1.60
Totals	0.54	1.60	1.60
B. TOTAL SUPPLY COSTS			
Recurrent (variable) Costs			
1. Generation/Transmission	0.25	n.a.	0.61
2. RE Distribution	0.11	n.a.	0.08
3. Connection	0.03	n.a.	0.02
4. Tariff	n.a.	0.44	n.a.
Subtotals	0.39	0.44	0.71
Fixed (Capacity) Costs			
1. Generation/Transmission	0.29	n.a.	1.15
2. RE Distribution	0.33	n.a.	0.17
3. Connection	0.10	0.27	0.05
Subtotals	0.72	0.27	1.37
Totals	1.11	0.71	2.08
C. NET INCOME / BENEFITS	-0.57	0.89	-0.48

NOTES: n.a. - not applicable

Financial generation and transmission costs based on capital costs of 5,200 Rs/kw (at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kw (at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

The recurrent costs of G&T include system losses of about 23 percent. 32306

TABLE 3.4-2B: ILLUSTRATIVE HOUSEHOLD (Middle Income) CUSTOMER ANALYSIS

BASE CASE: middle income (about 60% of rural population)
annual electricity use of 540 kwh with 0.36 kw peak
with peak coincidence factor of 65% at generation

	Financial Analysis		Economic Analy
	Utility	Customer	Society
A. REVENUES			
1. Tariff A-1	0.39	n.a.	n.a.
2. Connection Charges	0.34	n.a.	n.a.
3. Gross Benefits	n.a.	1.83	1.83
Totals	0.73	1.83	1.83
B. TOTAL SUPPLY COSTS			
Recurrent (Variable) Costs			
1. Generation/Transmission	0.25	n.a.	0.61
2. RE Distribution	0.13	n.a.	0.09
3. Connection	0.11	n.a.	0.08
4. Tariff	n.a.	0.39	n.a.
Subtotals	0.49	0.39	0.78
Fixed (Capacity) Costs			
1. Generation/Transmission	0.34	n.a.	1.38
2. RE Distribution	0.39	n.a.	0.19
3. Connection	0.34	0.69	0.17
Subtotals	1.07	0.69	1.74
Totals	1.56	1.08	2.52
C. NET INCOME / BENEFITS	-0.83	0.75	-0.69

NOTES: n.a. - not applicable

Financial generation and transmission costs based on capital costs of 5,200 Rs/kw (at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kw (at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

The recurrent costs of G&T include system losses of about 23 percent. 3230o

TABLE 3.4-2C: ILLUSTRATIVE HOUSEHOLD (Low Income) CUSTOMER ANALYSIS

BASE CASE: low income about 30% of rural population)
annual electricity use of 240 kwh with 0.30 kw peak
with peak coincidence factor of 65% at generation

	Financial Analysis		Economic Anal
	Utility	Customer	Society
A. REVENUES			
1. Tariff A-1	0.39	n.a.	n.a.
2. Connection Charges	0.76	n.a.	n.a.
3. Gross Benefits	n.a.	2.12	2.12
Totals	1.15	2.12	2.12
B. TOTAL SUPPLY COSTS			
Recurrent (Variable) Costs			
1. Generation/Transmission	0.25	n.a.	0.51
2. RE Distribution	0.14	n.a.	0.19
3. Connection	0.25	n.a.	0.18
4. Tariff	n.a.	0.39	n.a.
Subtotals	0.64	0.39	0.59
Fixed (Capacity) Costs			
1. Generation/Transmission	0.36	n.a.	1.47
2. RE Distribution	0.42	n.a.	0.21
3. Connection	0.76	1.23	0.37
Subtotals	1.54	1.23	2.05
Totals	2.18	1.62	2.94
C. NET INCOME / BENEFITS	-1.03	0.50	-0.82

NOTES: n.a. - not applicable

Financial generation and transmission costs based on capital costs of 5,200 Rs/kw (at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kw (at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

The recurrent costs of G&T include system losses of about 23 percent. 323wo

iii. While the case for household users is not as financially unfavorable as for tubewells, even if all RE fixed and capacity costs are grant covered, WAPDA will still incur a substantial loss in effect earning nothing on Generation and Transmission fixed costs and also falling short on recurrent costs. Such a policy is not financially viable over any long term period.

The columns labelled economic analysis of Table 3.4-2 (A to C) indicate the economic cost and benefit flows from society's perspective in the case of illustrative households. The economic benefits are based on the net savings (in comparison to kerosene lighting) and consumer surplus for other uses measured in economic prices (see Appendix D). The results shown in these tables and other economic analysis suggest the following comments and inferences:

i. the unit economic benefits are highest for the lowest income group because they use little electricity and what they use is mostly for high value basic lighting;

ii. On strictly economic criteria, with current policies, economic costs exceed benefits for all household groups;

iii. Under circumstances of a combination of decreased economic costs and/or increased economic benefits, households could become marginally economic. These circumstances are some combination of:
   a. a decrease in RE system costs as proposed in Chapter 5;
   b. a decrease in fixed (capacity) generation and transmission costs;
   c. increased direct benefits as a result, for example, of greater electricity use or higher consumer surplus and willingness to pay; or,
   d. the crediting of some indirect and/or complementary investment benefits.

   For example, if the direct benefits are underestimated by about 25% (as international comparisons indicate) and the cost reductions described in Chapter 5 are achieved, household use would be marginally economic.

iv. Introducing socio-economic considerations suggests that household use could be more viable than indicated by the economic analysis outlined above; the following specific factors warrant consideration in future work:
   a. introducing a social weight reflective of rural income equity objectives.
   b. introducing a social weight incorporating urban-rural income distribution equity objectives.

The implications of these comments and the importance of household tariff and connection policy reform are discussed below (Sections 3.6.2 and 3.6.3).

It should be noted that the estimates of the economic benefits of electricity for households are probably low. Insufficient information combined with low existing tariffs do not permit higher estimates without additional investigation. Such investigation is recommended as information from other countries and from private generators in Pakistan indicate that higher benefits are likely.

3.4.3 Financial Costs and Revenues and Economic Benefits and Costs - Cases of Illustrative Rural Industry Users

Following the pattern of the tables above, the columns labelled financial analysis in Table 3.4-3 present the financial income flows for an illustrative rural industry user cases representing two levels of electricity utilization: a base case of 1000 hours/year and a high utilization case of 2000 hours/year of operation. As in the earlier tables, the financial flows are shown for both the utility (WAPDA) and the customer with figures presented on a per kwh basis. The revenue figures are for the Tariff category B-1. Supporting details for this analysis can be found in Appendix F. The financial analysis results shown in Table 3.4-3 allow the following comments:

i. For the lower utilization level users WAPDA does not recover its financial costs by about 0.26 Rs/kwh,

ii. For the higher utilization level users WAPDA makes a financial excess of about 0.25 Rs/kwh; hence under current policies rural industry appears a user category for which WAPDA does not incur a financial loss;

Following the pattern above, the economic analysis of Table 3.4-3 shows economic cost and benefit flows from society's perspective in the cases of illustrative rural industry users. The economic benefits are based on the net savings in comparison to diesel based motive power. The results shown in these tables and other economic economic analysis suggest the following comments and inferences:

i. Based only on the direct (cost savings based) economic benefits only, the high utilization rural industry user is close to being economic.

ii. Under Some circumstances, high utilization rural industry could become strongly economic and the low utilization rural industry could become economic. As in the case with household users, this could result from a combination of decreased economic costs and/or increased economic benefits, these circumstances are some combination of:

   a. a decrease in RE system costs as outlined in Chapter 5;
   b. load management, for on-peak restrictions and improved power factors, which will require new tariffs;
   c. a lower estimate of fixed (capacity) generation and transmission costs;

TABLE 3.4-3: ILLUSTRATIVE RURAL INDUSTRY CUSTOMER ANALYSIS

BASE CASE: electric motor operating at 12 HP for 1000 hours/year in base case
high utilization case operates for 2000 hours/year
electric motor efficiency of 70% versus diesel engine efficiency of 17.5%
with peak coincidence factor of 65% at generation

	Financial Analysis				Economic Analysis	
	Utility		Customer		Society	
	Base	High Util	Base	High Util	Base	High Util
A. REVENUES						
1. Tariff B-1	1.36	1.19	n.a.	n.a.	n.a.	n.a.
2. Connection Charges	0.17	0.09	n.a.	n.a.	n.a.	n.a.
3. Gross Benefits	n.a.	n.a.	2.25	2.22	1.70	1.67
Totals	1.53	1.28	2.25	2.22	1.70	1.67
B. TOTAL SUPPLY COSTS						
Recurrent (Variable) Costs						
1. Generation/Transmission	0.25	0.25	n.a.	n.a.	0.61	0.61
2. RE Distribution	0.19	0.10	n.a.	n.a.	0.14	0.07
3. Connection	0.06	0.03	n.a.	n.a.	0.04	0.02
4. Tariff	n.a.	n.a.	1.36	1.19	n.a.	n.a.
Subtotals	0.50	0.38	1.36	1.19	0.79	0.70
Fixed (Capacity) Costs						
1. Generation/Transmission	0.51	0.26	n.a.	n.a.	1.95	0.98
2. RE Distribution	0.60	0.30	n.a.	n.a.	0.29	0.15
3. Connection	0.18	0.09	0.30	0.15	0.09	0.04
Subtotals	1.29	0.65	0.30	0.15	2.33	1.17
Totals	1.79	1.03	1.66	1.34	3.12	1.87
C. NET INCOME - BENEFITS	-0.26	0.25	0.59	0.88	-1.42	-0.20

NOTES: n.a. - not applicable

Financial generation and transmission costs based on capital costs of 5,200 Rs/kW (at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kW (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kW (at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kW (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

The recurrent costs of G&T include system losses of about 23 percent. 32306

d. increased direct benefits as a result, for example, of greater electricity use as the low utilization users grow strongly (a result found elsewhere); or

e. the crediting of some indirect and/or complementary investment benefits; in other countries where the necessary ex-post studies have been conducted, there are often such additional benefits indicated from rural industry electrification: increased productivity of existing labor and capital as well as additional employment and expansion triggered by electricity (usually in the presence of other complementary inputs such as credit).

If for example these factors suggested an increase of only about 10 to 15 percent in the high utilization case, rural industry would be economic. In the case of the low utilization industry, this might become economic if:

1. increased productivity and higher growth lead to an increase in electricity use; and
2. indirect and complementary investment benefits amounted are large; and
3. the cost reductions discussed in Chapter 5 are implemented.

iii. Rural industry could be more viable than indicated by the above economic analysis because of the rural income/employment associated with productivity increases, the small industry growth associated with the availability of an economic and reliable electricity supply and other complementary inputs. Studies to assess these changes in Pakistan are of great importance and should be initiated at an early date.

3.4.4 Financial Costs and Revenues and Economic Benefits and Costs - Cases of Illustrative Rural Commercial Users

Table 3.4-4 presents the financial income flows (for the customer and WAPDA) for illustrative rural commercial users. Two different use levels are considered: one including refrigeration and one without. The revenue figures are for the Tariff category A-2. The financial analysis indicates that:

i. WAPDA revenues are well above costs, with the excess of about .3 Rs/kwh; under current policies rural commercial users appear to be the only user category for which WAPDA receives a substantial financial excess; and

ii. Such customers' higher annual use and higher load factors (particularly with refrigeration use) lead to lower unit (per kwh) charges for the fixed customer connection cost and load factor dependent system costs (e.g. generation and transmission).

The economic analysis in Table 3.4-4 presents the economic cost and benefit flows from society's perspective. The results shown in these tables and other economic analysis suggest:

TABLE 3.4-4: ILLUSTRATIVE COMMERCIAL CUSTOMER ANALYSIS

BASE CASE: lighting and fan use plus range is based on with & without refrigeration annual electricity use of 540 kwh with 0.36 kw peak without refrigeration annual electricity use of 890 kwh with 0.51 kw peak with refrigeration with peak coincidence factor of 65% at generation

	Financial Analysis				Economic Analysi	
	Utility		Customer		Society	
Refrigerator:	No	Yes	No	Yes	No	Ye
A. REVENUES						
1. Tariff A-2	1.50	1.50	n.a.	n.a.	n.a.	n.a
2. Connection Charges	0.34	0.21	n.a.	n.a.	n.a.	n.a
3. Gross Benefits	n.a.	n.a.	2.34	2.20	2.34	2.2
Totals	1.84	1.71	2.34	2.20	2.34	2.2
B. TOTAL SUPPLY COSTS						
Recurrent (Variable) Costs						
1. Generation/Transmission	0.25	0.25	n.a.	n.a.	0.61	0.6
2. RE Distribution	0.13	0.11	n.a.	n.a.	0.09	0.0
3. Connection	0.11	0.07	n.a.	n.a.	0.08	0.0
4. Tariff	n.a.	n.a.	1.50	1.50	n.a.	n.a.
Subtotals	0.49	0.43	1.50	1.50	0.78	0.74
Fixed (Capacity) Costs						
1. Generation/Transmission	0.34	0.29	n.a.	n.a.	1.38	1.19
2. RE Distribution	0.39	0.34	n.a.	n.a.	0.19	0.16
3. Connection	0.34	0.21	0.76	0.46	0.17	0.10
Subtotals	1.07	0.84	0.76	0.46	1.74	1.45
Totals	1.56	1.27	2.26	1.96	2.52	2.19
C. NET INCOME / BENEFITS	0.28	0.44	0.08	0.24	-0.18	0.01

NOTES: n.a. - not applicable

Financial generation and transmission costs based on capital costs of 5,200 Rs/kw at generation) and recurrent costs of 0.245 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 6,000 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 15% with a 30 year life was used.

Economic generation and transmission costs based on capital costs of 30,000 Rs/kw at generation) and recurrent costs of 0.61 Rs/kwh delivered to the customer. RE distribution costs based on capital costs of 4,200 Rs/kw (at generation) and a recurrent charge for O&M of 5% of total capital costs. A discount rate of 10% with a 30 year life was used.

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i. Commercial users with refrigeration break even economically whereas the other commercial customer example is close to being economic. The potential RE cost reductions will lead to marginally economic results;

ii. In the refrigeration use case, the direct economic benefit estimate is a lower bound, hence even without indirect or complementary benefits (which likely exist), this use is likely quite economic.

3.4.5 Financial Costs and Revenues and Economic Benefits and Costs - Cases of Illustrative Villages/Settlements

The village analysis consisted of examining a mix of the different customer types discussed above to simulate the benefits and costs of rural electrification in a village context. This work was performed subsequent to the customer analysis and was used to examine a number of issues:

- RE financial and economic attractiveness on a village scale.
- the contribution of different customer types to total village economic benefits from RE.
- cost reductions and economies of scale for RE costs.
- RE intensification and extension economics.
- sensitivity analysis concerning various parameters such village size, customer mix, provincial differences, social weights, etc.

The village analysis accounts for the benefits, costs and electricity demands of aggregation of the above customers. This analysis, which is discussed in Annex G, can vary the mix of customers, their electricity penetration rates, and the villages supply costs. Financial and economic analyses, such as net present value of benefits and costs, are performed. Many of the results of the illustrative village analysis are weighted averages of the above customer analyses. Thus many of the village analysis results parallel the results of the above customer analyses. This situation occurs because the customer analyses were structured to capture the benefits and costs of RE in a village context. For example, in the customer analysis, the RE costs included allocated shares of village and area RE costs. Therefore, either the village and customer analyses can be used to examine an issue; however, one or the other may be more convenient.

Financial Analysis

As has been found for the individual customers, the financial attractiveness for RE varies significantly for the utility versus the customer:

i. As a unit, the gross benefits to the village are substantially higher than the costs for connection and tariffs.

TABLE 3.4-5: ILLUSTRATIVE MAIN VILLAGE ANALYSIS

BASE CASE: for details see Appendix G: 300 households: penetration - about 67% in year 10: 87 kw demand with 24% load factor at generation connected customer mix: 202 households, 15 commercial, 2 rural industry, 3 3 km of HT area distribution line required

	Financial Analysis		Economic Ana
	Utility	Village	Society
A. REVENUES			
1. Tariff	0.55	n.a.	n.a.
2. Connection Charges	0.27	n.a.	n.a.
3. Gross Benefits	n.a.	1.98	1.83
Totals	0.82	1.98	1.83
B. TOTAL SUPPLY COSTS			
Recurrent (Variable) Costs			
1. Generation/Transmission	0.25	n.a.	0.61
2. RE Area Distribution	0.16	n.a.	0.10
3. RE Village Distribution	0.06	n.a.	0.04
4. Connection	0.11	n.a.	0.08
5. Tariff	n.a.	0.55	n.a.
Subtotals	0.57	0.55	0.83
Fixed (Capacity) Costs			
1. Generation/Transmission	0.37	n.a.	1.48
2. RE Area Distribution	0.48	n.a.	0.22
3. RE Village Distribution	0.19	n.a.	0.09
4. Connection	0.33	0.53	0.16
Subtotals	1.36	0.53	1.95
Totals	1.93	1.08	2.78
NET INCOME - BENEFITS	-1.11	0.90	-0.95

NOTES: n.a. - not applicable

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ii WAPDA incurs a substantial loss on the village connection in that revenues cover less than one-half of costs. Tariffs cover only the recurrent financial costs of the system. Connection charges do not cover all of the connection capital costs; this is primarily due to the partial tubewell connection subsidy policy.

Table 3.4-5 presents such findings for an illustrative village (see Appendix G). An important point is that the financial position of the utility can be greatly improved because customers are willing to pay much more than they currently pay to the utility.

Economic Analysis

Again, as was found with the customer analyses, the economic benefits of RE do not cover the economic costs. As noted earlier, the benefits of RE are likely to be higher than actually exist. The uneconomic position of RE is largely due to the high costs of generation and transmission (G&T) and not to RE costs themselves. As discussed above, G&T costs form about three-fourths of total electricity supply costs. Economic benefits do not cover the cost of G&T although this situation could improve as better estimates of benefits are possible and as rural load factors improve through load management and growth. The benefits easily cover the recurrent costs of electricity.

Provincial Differences

As mentioned above, the benefits estimates will vary by province due to different mixes of customers and different benefits per customer. Chapter 6 notes that part of the future work in the area of village selection will involve surveys to better understand these variations so that decisions as to how to include them in benefit estimation can be made on a more accurate basis. At this time, it is important to note that the village selection procedure which is outlined in Chapter 4 compares villages within a district or tensil. Up to this level, the allocation of RE resources is done by using aggregate criteria such as rural population, non-electrified rural population, or development indices. Consequently, the village selection criteria are less vulnerable to biases due to provincial differences to the extent that the village benefits are based on population and numbers of rural industries and tubewells.

Sensitivity Analysis

Given the large uncertainty in the basic parameters used in these analyses, a number of sensitivity analyses were performed to indicate how the results would vary with different input values. Some of the conclusions are:

The gross benefits estimations are very likely lower bounds for the actual benefits. This is due to the lack of the detailed information needed. Household benefits estimations in other countries have found higher results. Furthermore, information from private power generators in the Karachi area indicate a much higher willingness-to-pay for

small amounts of electricity. The lack of information also prevented this study from estimating indirect benefits for some customers such as rural industry. If the actual gross benefits for this illustrative village were underestimated by one-third (or in other words the benefits in this study were increased by 50%), RE would break even.

To suggest how the illustrative village could become economic, several basic parameters are changed in a favorable manner. For example, if the discount rate is lowered to 5% (as suggested by Markandya, Ref 11) and a 30% RE costs savings is attainable, this village's net benefits break even. Most of the improvement is due to the lower discount rate. The RE cost savings reduce total costs by about 7% (including G&T). Similarly, if the long-run capital costs of G&T were lowered from 30,000 to 20,000 Rs/kw, the overall costs would be reduced by nearly 20%. These lower costs together with the RE cost reduction would leave the illustrative village with net benefits of about -0.3 Rs/kwh as opposed to the -1.0 indicated in Table 3.4-5.

Social Weights and Indirect Benefits

As discussed above, to examine broader equity objectives such as social policies aimed at improved equity between rural and urban areas or between income classes, the investment analysis could be performed using social weights which incorporate these policies. Such weights are largely political judgments based on some analyses (see UNIDO approach, Ref 8). In this study it is useful to note the implied social weights which would make RE household connection socio-economically attractive. For example, a social weight of about 40% would make household benefits approximately equal to costs. Based on the results on household above in section 3.4.2, such social weights would involve about a 40% premium on rural consumption. Such a premium is not an extreme value.

Similarly, some customers such as rural industry have indirect benefits that could not be captured due to information limitations. It is useful to note that for rural industry, the amount of such indirect benefits as a percentage of direct benefits needed to make RE connection economic varies from about 10 to 80% depending on the operating level of the business. These percentages are probably overestimates as the direct benefits measures in this study are only lower bounds.

RE Intensification and Extension

Investment allocation decisions will have to be made among three options:

(1) connection of more customers in electrified settlements,
(2) connection of additional settlements and villages from existing area distribution lines, and
(3) connection of additional villages from new distribution lines.

Clearly these three options are listed in order of increasing cost. However, the magnitude of cost differences will vary significantly. Option 1 is much less expensive when there is sufficient capacity in the settlement LT lines and transformers (or when conductors can be upgraded at relatively low cost). Similarly, connecting nearby settlements is less expensive when the 11 kV lines have sufficient excess capacity taking into account medium-term needs for demand growth in existing connections. Other factors to be considered include the extent that rehabilitation and line strengthening is needed, as the cost differences between these options declines. Regardless of any possible lessening of costs differences, efficiencies are to gained by installing new connections during rehabilitation and strengthening work.

The most attractive case for intensification occurs when there is excess capacity with regard to RE area and village distribution. In this extreme, the RE portion of electricity supply could be reduced to only the customer connection costs or by about 25 to 35 percent depending on the customer type. Under such conditions, about twice as many connections could be made with the same RE budget.

With a goal of maximizing the number of customers and revenue at the earliest date, intensification is generally the most attractive investment. Allocation of investment funds to extension is justified on the basis of equity and social criteria and is a political decision.

3.5 Ability to Pay (ATP) and Willingness to Pay (WTP): Observations and Inferences for Policy

Ability to pay reflects the financial capacity of the customer to pay for electric service. The measure of capacity to pay for services must reflect both income levels and the cash flow characteristics of this income. These must be considered relative to both overall customer expenditure needs and characteristics of the cost/payment for the electric service. In particular capacity to pay considerations must reflect the lumpiness of expenditure requirements (such as connection charges and internal wiring costs) and the absence or presence of mechanisms to finance such lumpy expenditures over a period of time and the terms of such financing.

Willingness to pay in economic terms, as opposed to ability to pay, measures the total price the consumer would be willing to pay for a particular quantity of electricity as opposed to the offered sale price. It measures the sum (or integral) of what the consumer is willing to pay for each incremental unit of consumption. The willingness to pay will be above the offered market price in that it includes consumer surplus. The willingness to pay may be extended to include considerations of consumer perceptions of:

i. the quality of service (electricity reliability);

ii. other factors, including convenience, safety, improved "quality" of lighting, etc.

However a consumers willingness to pay does not adequately characterize the potential for tariff changes and greater cost recovery. In addition the consumer may be influenced by his perceptions regarding the suppliers billing and collection efficiency, that is the supplier's collection procedures and the ease of circumvention. The consumer may perceive that he can avoid payment and will do so regardless of his willingness to pay unless the suppliers collection efforts improve. This appears to be the case for many rural (and urban) consumers in Pakistan.

3.5.1 Ability to Pay and Willingness to Pay of Tubewell Users

Irrigation markedly increases agriculture income at the farm level; the financial returns to irrigation are considerable. The gross financial returns to tubewell irrigation (or low lift) irrigation depends on whether this source of irrigation water is the only source or a supplement to other sources of irrigation (canals). In the later case there is less pumping and the capital costs (prime mover/transmission/pump and well and piping) must be amortized over fewer hours and lower volume of water. The case of pumping for supplemental irrigation is the general case presented in the analysis above. It is obvious that many thousands of current users have both the capacity and willingness to pay current tariffs and connection charges. From the perspective of needed policy changes, the more important issue is whether these users have the capacity and willingness to pay tariffs and connection costs that are much higher.

The financial analysis presented in Table 3.4-1 suggests that users have the capacity to pay tariffs that would cover WAPDA's full financial costs. Such tariffs would require unit charges about 20 percent higher than the present ones (Tariff D) and customer assumption of full cost of connection. For some users, capacity to pay the large connection costs would be dependent on loans being available. The financial analysis also suggests the willingness to pay such tariffs but their perceptions of WAPDA and Governments resolve could be an issue.

Tariffs that cover the full economic costs would require much higher unit charges especially in the absence of load management. Even with pumping use only off peak, tariff increases to cover the full economic costs will need to be large. The capacity to pay such tariffs is therefore based on the value added that comes from irrigation, but the willingness to pay such tariffs is unlikely to be sufficient, since farmers are likely to chose the less costly diesel option instead.

3.5.2 Ability to Pay and Willingness to Pay of Household Users

Ability to pay and willingness to pay of household users is much dependent on household income. It is apparent from such information as available that there are a very large number of present rural household users with both the ability and willingness to pay present tariffs and connection charges; most of these are in the higher (by rural standards) income groups. A major problem for a large percentage of potential rural household users, under existing policy a major problem is the lumpiness of the costs of connection (official and "unofficial") as well as the initial internal wiring costs. Under existing policies, connections are scarce, there is a considerable queue, and "unofficial" charges are often quite large. For average income households, the total first costs can represent 10 to 15 percent of annual income. For low income households the total first costs can be 20 percent of annual income, well beyond the capability of households to pay without credit. Provision of credit for all consumer capital costs (including internal wiring, particularly for low income households) or another mechanism to integrate these costs as part of the monthly bill should be considered (see discussion in Section 3.6.3 below.)

Given the importance of achieving a greater degree of financial if not economic cost recovery by WAPDA, an important issue is whether some household users have the capacity and willingness to pay tariffs that are much higher. The financial analysis suggests that high and middle income households have the willingness to pay tariffs that would cover WAPDA's full financial costs, although this does not appear to be the case for low income households. Independent of possible tariff increases, in light of their limited financial capability, special tariff and connection policies should be implemented for low income households in any case (see discussion in Section 3.6 below). High and middle income households may be able to pay higher tariffs because the increased costs are less than their discretionary expenditures, as estimated from the 1984-85 households expenditure survey (Ref 141).

3.5.3 Ability and Willingness to Pay of Rural Industry and Commercial Users

As in the case of other users, the evidence from existing connections indicates both the capacity and willingness to pay at present tariffs among these user groups and the financial analysis reinforces this evidence. Again as with the other users, an important issue is whether rural industry and commercial users have the capacity and willingness to pay tariffs and connection costs that are higher. For these users, WAPDA is already achieving more than full financial cost recovery. To cover economic costs would, however, require higher tariffs and the financial analysis suggests that these users have the capacity to bear some increase in tariffs to close the gap between current tariffs and those which would cover full economic costs.

3.6 Synthesis of Analysis Issues and Inferences for Needed Policy Changes

This section integrates the findings of the master plan preparation study. This integration draws not just from the results summarized in this chapter but also also from previous chapters as well as the results presented in Chapters 4 and 5. This synthesis of issues suggests needed policy changes. Many of the policies are interrelated, but for the purposes of presentation, suggestions regarding these changes are separated and presented with respect to:

1. policies regarding intensification (backfill in existing villages) versus extending the system to new villages;

2. consumer connection policy;

3. tariff policy;

4. subsidy policy;

5. village/settlement selection policy; and

6. technical standards, and design and supply alternatives.

The proposed new institutional structures through which these changes should be implemented were outlined in Chapter 2.

3.6.1 Intensification Versus Expansion to New Villages

The future policy of the RE program, reflecting both equity and economic efficiency criteria, would emphasize intensification (backfill in electrified villages) as opposed to primarily extending the system to new villages. This is different from the existing program which provides few resources for new connections in villages/settlements already electrified. The characteristics of the policy to emphasize backfill would include:

1. Allocating, at least for the first 3 years (and then reviewed), half the RE budget for backfill.

2. The backfill budget policy is to emphasize connecting households, commerce and industry located within the settlement but not tubewells.

3. This policy is to be complemented by the consumer connection policy changes (items 1 to 7 in Section 3.6.2 below) and the village/settlement connection policy changes (items 1 to 3 in Section 3.6.5 below).

At present, the RE Rehabilitation budget is included under Distribution Rehabilitation. Rehabilitation is a necessity for intensification of the rural system, requiring major investments. Funds for rehabilitation should therefore be linked to the scope of the intensification program.

3.6.2 Consumer Connection Policy

The consumer connection policy for the future RE program balances equity criteria with minimum financial solvency criteria and would include:

1. Minimum household target connections of at least 70 percent of the households in all electrified villages/settlements; this target to hold for both newly electrified villages/settlements and the increased backfill component of the program (see Section 3.6.1 above). This target is set to achieve equity goals of connections to all households. This policy should be coordinated with item 4. and item 1. in Section 3.6.3 below such that affordability to low income households is ensured.

2. Adequate funds and materials (meters etc.) available to meet the 70 percent targets so that service connections become "less scarce" and hence less likely to require "unofficial" payments.

3. Expansion of surveillance activities to monitor connection procedures and minimize "unofficial" connection payments.

4. Introduction of an addition to the RE program of a zero first cost (service connection) option aimed at low income households. This program would finance (either through loans or special tariffs) the costs of both the service and internal wiring including light fixtures. This policy would be complemented and reinforced with the introduction of a "rural lifeline" tariff category (see item 1 in Section 3.6.3 below). This option would only be available to customers with current-limited service.

5. Requirements that all new tubewell connections be required to:
   - i. be fitted with capacitors for power factor correction or connection is disallowed;
   - ii. adopt the reinforcing new tariff category D-LM (see item 2 in Section 3.6.3 below) and be fitted with the necessary load management and metering equipment, or connection is disallowed;
   - iii. bear the full cost of connection (partial finance will be an option under the new tariff);

6. An absolutely immediate crash program of field testing of tubewell load management complemented by the program outlined in 7. immediately below.

7. Design and implementation of a retrofit program to accomplish the equivalent of item 5. immediately above, to cover all existing electrical tubewells within the next 5 years, i.e. during the 7th Plan period.

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Application Procedures

The current imbalance between backfill versus extension to new villages/settlements and general lack of materials and related resources for service connections in general produces a high scarcity value on service connections and a very large queue of customers waiting for service. As mentioned elsewhere the scarcity value often leads to unofficial payments not captured by WAPDA. The lack of materials and inability to respond to potential customers leads to many delays.

Fundamental problems are the lack of materials and resources for backfill connections and insufficient resources, materials and coordination in the case of newly electrified villages. Furthermore, when connections are available, there is the need to assist some customers with financing connection costs.

The application for service process should be shorter in time, less open to incentives for unofficial payments, but not necessarily simpler overall. Prior to electrification, all potential customers should be canvassed, regarding their interests in having service and of which category including the new lifeline category. Deposits should be taken only when the needed resources are available so that service can be provided quickly. In the case of new villages or large village backfill programs, this village-wide activity should take place in a brief period of time.

The existing application procedure should be simplified to include the following :

(1) Any applicant may apply for connection through deposit of a fixed connection fee in any commercial bank. Upon receipt of money, the customer should be provided with a receipt and priority number by the concerned division immediately after receipt of applications from the bank.

(2) Flat rates for connections should be fixed for different types of connections, current ratings and distance from the distribution line.

(3) The planning engineer should prepare technical plans for the connections and estimate of material for all connections. Customers who are too far away and do not fall under existing classifications of distance should be treated as special cases. In all other cases a work order should be prepared and material requisitioned within a specified time. Separate procedures should be developed for the special cases.

(4) The customers should be informed about the cost estimate and last date for deposit of the cost of connection. Upon receipt of the connection cost the customer should be informed about the date when connection will be given.

(5) For all activities specific dates should be given.

(6) Simplification in the procedure should be studied in detail through interviews with customers as well as WAPDA staff. More detailed analysis and field studies are needed to evolve connection a procedure which is free from problems.

A small study is needed to determine if responses on application forms match the actual appliance and electricity use patterns after connection, to determine if the application should be changed or simplified. On the other hand, additional data may be collected during the application process, for load and other research efforts. These data may include the size of the household, or the number of rooms in the house.

3.6.3 Tariff Policies

The tariff policies should reflect financial, economic and equity criteria and must be considered in conjunction with the subsidy policies. The objectives of the tariff policies should include a minimum target of financial solvency for the rural component of the supplier (WAPDA) via immediate tariff changes. The equity criteria should be reflected in both the tariff design for low income households and if needed the complementary budgetary transfers from Government to WAPDA. Economic criteria should also be reflected in the longer term direction of tariff changes. Currently, tariff changes are the subject of:

i. ongoing WAPDA tariff rationalization planning efforts; and,

ii. a tariff study financed by the Asian Development Bank.

The tariff changes outlined in the points immediately below may need to be modified in light of the results of these two ongoing efforts. Based on the master plan preparation, the following changes are needed:

1. Introduction of a new household tariff and service connection category (see item 4 in Section 3.6.2 above). This tariff, referred to as a "rural lifeline" tariff and service connection option would be aimed at low income households. The tariff and service would be characterized as follows:
   i. current limited service of up to a maximum of 0.2 KW; and
   ii. unmetered monthly flat rate tariff (to be further studied) but the the monthly charge would be based on a use rate of about 200 kwh per year. Use of 200 kwh/year is very approximately based on 2 to 3 light sources and 1 to 2 fans. Load research and pilot programs could be used to determine the specifics of this tariff.
   iii. The cost of the service connection, internal wiring and basic light fixtures should be covered by a monthly financing program in order to increase customer penetration. The initial large cost should be eliminated if necessary to avoid inhibiting connections.
   iv. The purpose of the flat rate and the current limiter is to develop the lowest cost type of connection so as to minimize the financial and administrative burden on WAPDA while attaining high household penetration rates.

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2. Revision of the tubewell tariff structure (to be studied further **immediately**) to:
   i. Complement the new connection and retrofit policy (items 5. and 7. in Section 3.6.2 above).
   ii. Eliminate the flat rate option.
   iii. Introduce a new tariff category D-LM (Load Managed) for the only new tubewell connections to be allowed (see item 2 in Section 3.6.2 above) this tariff to cover at a **minimum** WAPDA's full financial costs (recurrent and fixed); this tariff to also be applicable for the future "retrofitted" connections.
   iv. Increase the charges in tariff category D such that:
      a. the energy charges cover at a **minimum** full recurrent financial cost to WAPDA; and
      b. the capacity charge covers at a **minimum** full fixed (capacity) financial cost to WAPDA.
   v. Introduce other changes to complement the changes in connection policies (see item 5 in Section 3.6.2 above); this will require, in the case of a loan, an additional monthly loan repayment fee.

3. Increase all (but the new "lifeline") household tariffs:
   i. to recover a greater degree of the financial costs of service;
   ii. to capture higher income ability by having an increasing block structure; and,
   iii. so that commercial and small industry users have no incentive to use this category.

4. Plan and implement continuing examination and revision of rural tariffs. Such program to aim to increasing all tariffs over time (except the rural-lifeline) towards economic tariffs if consumer capacity to pay is adequate.

Improved Revenue Collection

There are steps that can be taken to improve revenue collection:

1. The introduction of the current-limited rural lifeline rate should improve net revenue collection. Since this is a flat monthly rate there is no meter reading hence lower administrative costs.

2. For other categories of service, bimonthly meter reading should also increase net collection by decreasing collection costs.

3. The tariff change discussed above (increased tariffs for high household consumption rate blocks) will prevent small commercial users from using the household category, and hence improve revenues.

4. The most important mechanisms for improved revenue collection are an integrated strategy of more effective surveillance and enforcement of disconnection procedures. Such approaches should be complemented by a better understanding of the rural load at the customer, village and feeder levels. With the advent of computerized customer records, there are straight forward approaches to compare actual loads and revenues to estimated loads and revenues. Comparisons will allow identification of discrepancies and losses, and will allow a better targeting of surveillance efforts. To assist in this process, better information to allow prediction of customer use is needed; such information includes ownership of electrical equipment and appliances, and can come from surveys undertaken for other purposes.

3.6.4 Subsidy Policies

As in the case of tariff policies, subsidy policies will need to be consistent with the other ongoing studies. Subsidy policies should extend beyond the tariff policies. In complement with the tariff policy, the subsidy policy should be aimed at achieving overall financial solvency of the rural component of WAPDA defined as a reasonable financial return on assets. The subsidy policy should have the additional focus of minimizing the cross subsidies. The subsidy policy must be based on detailed cost accounting so that the cost of rural electrification is clearly discernible on a very disaggregated basis. The subsidy polices will need additional analysis as rural electrification cost accounting procedures are implemented. But certain changes are needed:

1. Implementation of rural electrification cost accounting (mentioned initially in Chapter 2) to allow detailed estimation of the full financial costs of rural electrification. It is desirable and feasible that all relevant costs should be allocated separately to the rural system, including energy charges (metered at feeders) with full recurrent and capital cost accounting.

2. Implement an annual recurrent costs budgetary transfer from Government to WAPDA to cover financial losses now incurred from rural system operation. The financial principle should be introduced now. The details of the policy will require additional analysis and initial cost accounting efforts (item 1 above). Necessary transfers to cover the subsidy should decrease as the needed tariff policy changes (items 2 and 3 in Section 3.6.3 above) are implemented. Initially the transfers will be on a national estimate basis. As the detailed rural system cost accounting systems are developed and implemented by the new headquarters REO and the AEBs, the necessary recurrent budget subsidies should be pinpointed down to division level in Distribution.

3.6.5 Village/Settlement Selection Policy

The village/settlement connection policies should combine both economic and equity criteria. The approaches are an immediate extension of planning work that is being done to some degree in the AEBs. The technical and financial aspects of this approach should be a regular part of utility management. The suggested economic analysis is similar and in some aspects simpler than has been done in the past to examine some internationally financed RE projects in Pakistan. The important changes/revisions to policy are:

1. Immediate completion of the village/settlement data base to allow application of the area planning village/settlement to go forward in all AEBs.

2. Initial (next year) allocation of the National RE budgets to the Provinces and allocation of the Provinces' RE budgets to its districts in accordance with the procedure (or simple modification) which weighs rural population and development potential. Undertake a study of possible revisions to the allocation procedures to districts for use in subsequent budgets.

3. Select (i) unelectrified settlements in villages which have had at least one settlement electrified and (ii) villages/settlements in unelectrified villages by the area planning analysis method detailed in Chapter 4. Investments in villages/settlements (or clusters of villages/settlements) to be selected starting from the highest economic Benefit/Cost (B/C) ratio (even if less than 1) and proceeding in the order of decreasing B/C until the area budget is exhausted. The RE costs per village will be a function of a village's location relative to both the grid and to other villages. The RE benefits will be a function of the types and numbers of potential customers.

3.6.6 Technical Standards and Supply Alternatives Policies

The policies with respect to technical designs and standards and supply alternatives must reflect technical options evaluated in the light of economic costs and benefits. These policies should achieve a goal of having a "Pakistani solutions to the problems of RE in Pakistan" by drawing as much as possible on the past experience both in Pakistan and other countries which have addressed similar problems. The policy changes needed include:

1. Immediate issuance of a set of preliminary technical standards and guidelines to the AEBs (based on the work of Chapter 3 and supporting Appendices) to facilitate the achievement of cost reductions on the order of 30 percent
2. The incorporation of these guidelines (item 1 immediately above) in the technical aspects of area planning (see item 3 in Section 3.6.4 above) and in the work order implementation procedures for RE village/settlement investment project preparation and execution.
3. Start of ongoing further studies to develop final technical design, standards, and procedures guidelines for the AEBs.

3.7 Summary

3.7.1 Backfill Versus Expansion to New Villages

The future policy of the RE program, reflecting both equity and economic efficiency criteria, would emphasize intensification (backfill in already electrified villages) as opposed to primarily extending the system to new villages. This is different from the existing program which provides inadequate resources for new connections in villages/settlements already electrified. The characteristics of the policy to emphasize backfill would include:

1. Allocating (at least for the first 3 years, and then reviewed) half the RE budget for backfill.

2. The backfill budget policy will emphasize connecting households, commerce and industry located within the settlement, but not tubewells because of their currently highly subsidized position and the availability of an alternative energy source.

3. This policy is to be complemented by the consumer connection policy changes.

3.7.2 Consumer Connection Policy

The consumer connection policy for the future RE program balances equity criteria with minimum financial solvency criteria and would include:

1. Minimum household target connections of perhaps 70 percent of the households in all electrified villages/settlements; this target will hold for both newly electrified villages/settlements and the increased backfill component of the program. This target is set to achieve equity goals of connections to all households. This policy should be coordinated with item 4. below in order that affordability to low income households is assured.

2. Adequate funds and materials (connection cables, meters etc.) to be made available to meet the penetration targets. This will reduce the scarcity of service connections and hence reduce unofficial payments.

3. Expansion of surveillance activities to monitor connection procedures and minimize unofficial connection payments.

4. Introduction of in addition to the RE program of a zero first cost (service connection) option aimed at low income households. This program would finance (either through loans or special fixed charge tariffs) both service and internal wiring and light fixture costs. This policy would be complemented and reinforced with the introduction of a "rural lifeline" tariff category. This option would only be available to customers with current-limited service.

5. Requirements that all new tubewell connections be required to:

   i. be fitted with capacitors for power factor correction;
   ii. adopt the reinforcing new tariff category D-LM and be fitted with the necessary load management and metering equipment;
   iii. bear the full cost of connection (partial finance will be an option under the new tariff);

6. An immediate crash program of implementing load management on all existing tubewells including the development of a retrofit program to accomplish the equivalent of number 5 immediately above, within the next 5 years, i.e. during the 7th Plan period.

3.7.3 Tariff Policies

The tariff policies should reflect financial, economic and equity criteria and must be considered in conjunction with the subsidy policies. The objectives of the tariff policies should include a minimum target of financial solvency for the rural component of the supplier (WAPDA) via immediate tariff changes. The equity criteria should be reflected in both the tariff design for low income households and the complementary budgetary transfers from Government to WAPDA. Economic criteria should also be reflected in the longer term development of tariff changes. Currently, tariff changes are the subject of:

i. ongoing WAPDA tariff rationalization planning projects; and,

ii. a tariff study financed by the Asian Development Bank.

The tariff changes outlined immediately below may need to be modified in light of the results of these two ongoing projects. Based on the master plan preparation, the following changes are needed:

1. Introduction of a new household tariff and service connection category. This tariff, referred to as a "rural lifeline" tariff and service connection option would be aimed at low income households. The tariff and service would be characterized as follows:

   i. Current-limited service of up to a maximum of about 0.2 KW; and
   ii. Unmetered monthly flat rate tariff (to be further studied) for which the monthly charge could be based on a use rate of about 200 kwh per year. Load research and pilot programs could be used to determine the specifics of this tariff.
   iii. The cost of the service connection, internal wiring and basic light fixtures should be covered by a monthly financing program in order to increase customer penetration. The initial large cost should be eliminated, if necessary, to avoid inhibiting connections.
   iv. The purpose of the flat rate and the current limiter is to develop the lowest cost type of connection so as to minize the financial and administrative burden on WAPDA while attaining high household penetration rates.

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2. Revision of the tubewell tariff structure (as an immediate priority) to:

   i. Complement the new connection and retrofit policy;
   ii. Eliminate the flat rate option;
   iii. Introduce a new tariff category D-LM (Load Managed) for the only new tubewell connections to be allowed, this tariff to cover at a minimum WAPDA's full financial costs (recurrent and fixed) and to also apply to all future "retrofitted" connections;
   iv. Increase the charges in tariff category D such that:
      a. the energy charges at a minimum cover the full recurrent financial cost to WAPDA; and,
      b. the capacity charge at a minimum covers the full capacity financial cost to WAPDA.
   v. Introduce other changes to complement the changes in connection policies; this could require the provision of a loan, which would be repaid by an additional monthly loan repayment fee.

3. Increase all (but the new "lifeline") household tariffs:

   i. to recover a greater degree of the financial costs of service;
   ii. to capture the ability to pay among high income households by implementing an increasing block structure; and,
   iii. to ensure with a progressive tariff that commercial and small industry users will not have an incentive to use this tariff category.

4. Plan and implement continuing examination and revision of rural tariffs. This review would be aimed at increasing over time, all tariffs (except the rural-lifeline) towards economic (long run marginal cost) tariffs if consumer capacity to pay is adequate. Such examination should consider the different impacts on the four provinces.

3.7.4 Subsidy Policies

As in the case of tariff policies, subsidy policies will need to be consistent with the other ongoing studies. Subsidy policies should extend beyond the tariff policies, and in conjunction with the tariff policies, should be aimed at achieving overall financial solvency on the rural component of WAPDA by providing reasonable financial returns on assets. The subsidy policy should have the additional focus of minimizing cross subsidization and must be based on detailed cost accounting so that the cost of rural electrification is clearly discernible on a totally disaggregated basis. The subsidy polices will need continuing additional analysis as the rural electrification cost accounting procedures are fully implemented. Some changes can be implemented now:

1. Initiate rural electrification cost accounting systems to allow detailed estimation of the full financial costs of rural electrification, including all capital costs, value of energy supplied and sold and all recurrent costs. This will enable rural accounts to be prepared for each AEB and a composite account for WAPDA.

2. Implement an annual recurrent costs budgetary transfer from Government to WAPDA to cover the identified financial losses now incurred from the rural electrification system. This financial principle should be introduced now. Necessary transfers to cover the subsidy should decrease as the needed tariff policy changes are implemented. Initially the transfers will be on a national estimate basis. As the detailed rural system cost accounting systems have been fully developed and implemented by the new headquarters REO and the AEBs, the necessary recurrent budget subsidies should be pinpointed at all levels in the distribution system.

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Chapter 4

Setting Priorities for Investment in Rural Electrification: Problems and A Suggested Approach

4.1 Introduction

This strategic master plan for rural electrification has, as one of its components, the development of operational criterion and procedures for setting priorities for village selection. In effect this means setting priorities for investments in rural electrification by developing a methodology that will reflect the objectives of the GOP for investments in rural electrification. The application of this methodology will be a classical sectoral resource problem of optimizing (economically) the allocation of scarce resources. The Planning Ministry suggests that the approach should be looking for "development with equity" (Draft 7th FYP, p.52 Ref. 127). The planning literature conventionally converts this goal into one of "maximizing economic benefits subject to constraints on the distribution of the benefits to different segments of society."

In order to reach an economic optimum for rural electrification (RE) resource allocation, it is necessary to estimate the economic costs and benefits of electrification for each village by customer type. Some estimates of these benefits were discussed above in Chapter 3 for the different customer types. In principle, this information is needed in reasonable detail for each province in the country. Cost analysis was performed to estimate connection, village and area distribution, and substation costs. To undertake socioeconomic analysis, it is then required to know the limits to be placed upon the social distribution of benefits and costs at the village, provincial, and national level.

Based upon such information it is possible to devise a constrained optimization model that would allow for the optimal national allocation of the rural electrification funds over time. This model would identify the individual villages to be electrified as well as the extent of electrification in each village for the entire country. Given the numbers of villages and settlements and the numbers of provinces and districts in Pakistan, this will be a difficult task requiring substantial resources. The model approach will also need to take into account the socio-political aspect of RE resource allocation. Economic theory does not have a widely accepted method for incorporation of this aspect. Economic (benefit-cost) analysis addresses the issue of how much "we" get, when, and how, but not with who gets what. Politics, on the other hand, focuses on who gets what while also effecting when and how.

Any practical and operational planning analysis of rural electrification has to be able to address all of these dimensions in order to be useful to political decision-makers. Estimating the benefits of rural electrification (the "what" above) is in itself very difficult, as outlined earlier in Chapter 3 and detailed in the Appendices. The "when" and the "how" of RE depend to a large extent on the administrative and political culture. In this plan, an attempt is made to define criteria and planning and implementation procedures to make the answers to "when" and "how" more orderly and cost effective. But those involved in the rural electrification planning process (such as those who worked on this master plan and those responsible for subsequent implementation) should remember that the nature of the administrative and political cultures are also important to the final allocation of benefits.

4.2 A Step Wise Procedure for Setting RE Investment Priorities

The objective is to devise a method for allocating investment resources to RE. There are many ways of proceeding with such a problem, but the master planning approach has embraced the virtue of simplicity. It was decided not to use complicated economic models while at the same time not to abandon economic principles. The planning approach was selected incorporating the following criteria:

i. It should not require too much data or complex models for the analysis. Any data which is required should be available or immediately collectible.

ii. The planning procedures should be straight forward enough to be applied by field staff (with assistance and guidance from WAPDA headquarters and others).

This approach will result in having a workable, formalized set of procedures and criteria available for decision-making on investment priorities at all levels. There will also be a detailed instruction/reference manual for field staff engaged on area mapping, design, costing, planning and selection procedures.

In order to incorporate both economic and political inputs to the RE investment priorities for village selection, a two part process in recommended. The first part - budget allocation - is a set of procedures for allocating budgets from the Federal Government to the Provinces and then from the Provinces to the districts and/or tehsils. The second part - village ranking and selection within the district and/or tehsil budget allocations - is a planning procedure which ranks village-level investments on an area or cluster basis using benefit/cost analysis.

The procedure for budget allocations from the federal to provincial level should be studied to consider alternatives to the current one. Some alternatives that should be considered are rural population, numbers of rural villages, or numbers of un-electrified rural villages.

The proposed procedure for the budget allocation from provinces to districts is based on the rural population and the development potential in each district. The development potential would serve as an indicator of the additional benefits possible from electrification due to the prior existence of other district infrastructure such as markets, credit, literacy, roads, and industry.

This step-wise procedure is based upon judgements about the administrative and political environment and upon availability of data. Budget allocations and actual village selection should be implemented by the appropriate national, provincial, or local governments, while WAPDA (in the REO or AEB's) will conduct most of the necessary cost, benefit, demand, and other technical computations in cooperation with government agencies. This procedure is discussed in detail in the following section of this Chapter.

The application of economic principles is tempered by political and bureaucratic considerations. In the illustrative application for this master plan report, economic data and analysis for benefit-related parameters were prepared by the master plan team to be used in the area planning procedures. These parameter estimates could be used in initial applications of the procedures. However, as discussed earlier one of the functions of the new REO would be to revise these estimates as well as to provide guidance to the field teams which would undertake the area planning step of the investment planning procedure.

The planning steps for the budget allocation are to be implemented at three levels of government -- the federal government, the provincial governments, and the districts/tehsils. There is an appropriate step of the investment analysis at each of these levels of government based upon the special concerns of each level. The Federal Government is interested in the broad allocation of the resources among the provinces and has particular concern over regional disparities in income and infrastructure. At the provincial level, major concerns are also with issues of inter-class and urban/rural differences as well as with regional development disparities. The provinces are the major implementors of development policy and hence concern themselves with development issues. As WAPDA is the executing agency for RE, the area re-planning procedure (and implementation) at the provincial district level will eventually be by the particular WAPDA-AEB organization which covers that district.

At the district level, area issues are salient because the RE projects have to have specific locations. This spatial dimension is one of the technological imperatives of RE that leads to intense political interest at the district level. This does not mean, however, that politics is not a major determinant of the outcomes at the two higher levels.

There is another distinguishing feature of the proposed planning procedure that is unique and needs some explaining. The village ranking and selection procedure does not explicitly exclude regions, districts, or villages from consideration for RE solely on the basis of distance from a grid station or from a distribution line. Social, political, and economic rational together should dictate the choice of which villages should be electrified, not just a narrow technical criteria. Excluding areas on the basis of distance from grid facilities may eliminate areas and villages that could be attractive fo electrification either from the grid or from successfully electrified using decentralized options. The decentralized options should receive consideration alongside the conventional grid options, and be evaluated based upon the same criteria.

4.3 Budget Allocatic · the Federal Government to the Provinces

Allocation of resources among major entities, such as states in the United States or provinces in Pakistan, is a highly political activity. In the United States it is often difficult to reach a compromise other than on based upon the relative population size of the states. Such compromises are reasonable given the nature of the funding for programs based upon federal taxes which are highly influenced by the absolute sizes of the states' populations. Some sort of population weighting is for central allocation of funds to the provinces for RE in Pakistan. This approach is implied in the Draft 7th FYP and the Accelerated Rural Electrification Plan (Ref. 27). The allocation of some central-provincial financial programs in Pakistan appear to be based upon a population formula which allocates 90% of the funds to the provinces based upon their total population and the remaining 10% is split evenly between Baluchistan and NWFP in addition to their proportionate share of the first 90%.

For rural development programs, many other population weighted algorithms suggest themselves. Table 4.3-1 shows some of the relevant provincial data dealing with RE. The basic data used in this table are drawn from the Accelerated Rural Electrification Program. Table 4.3-2 shows what would happen if 100 units of capital expenditures were allocated to the provinces for RE based upon several different population based weighting schemes. Column 1 shows the allocation based upon the policy for financial allocations of the Federal Government with 5% each to NWFP and Baluchistan and the remaining 90% to all provinces proportional to their total population. This is labelled the "recent policy" (from the standpoint of RE). Column 2 shows an allocation directly proportional to the rural population alone. In column 3 is an allocation directly proportional to the numbers of non-electrified villages (taken from the Proforma PC-1 (Ref 72)) as reported. Column 4 shows the results when this allocation is weighted by an estimate of the size of the rural population. Finally, column 5 reports the proportions implicit in the Accelerated Rural Electrification Plan, which may be assumed to be the current federal policy for RE.

If data were available, other allocations could be examined. For example, if data on non-electrified rural population or on electrified settlements were available, allocations based upon them could be examined and compared to the others in Table 4.3-2. Other methods could be based upon the low income population weighted by the costs of electrifying the villages. This would incorporate both the cost and benefit sides.

The results of Table 4.3-2 are slightly disconcerting: depending upon which algorithm is chosen the individual provinces would receive widely differing percentages of the total budget. For example, the "recent" federal policy would consistently allocate substantially less funds to the Punjab than any of the other algorithms which reflect either rural population or rural electrification needs or some combination of both. Conversely, the "recent" allocation favors the Sind, NWFP, and Baluchistan over any of the competing allocations.

TABLE 4.3-1

PROVINCIAL DATA ON RURAL ELECTRIFICATION

PROVINCE	Million Rural Pop. 81	No. Vill. 1981	No. Vill. Elect.81	1991 TARGET Num. Vill. Electrif.	1991 TARGET Outlay Percent	Cost per Vill. Rs	Total Populatn.	Urban Percent
PUNJAB	34.14	25399	9780	12188	63	927000	47116	28%
SIND	10.81	5763	2541	2642	10	697000	18966	43%
NWFP	9.25	7809	1404	5294	15	508000	10885	15%
BALUCHISTAN	3.65	6110	686	4341	10	391000	4305	15%
FATA	2.17	1456	728	521	2	600000	2175	0%
	60.02	46537	15139	24986	100%		83782	28%

Source: Ref 27

TABLE 4.3-2

ALLOCATIONS USING DIFFERENT ALGORITHMS
And Differences with 1991 Targets

PROVINCE	(1) Recent Policy	(1) Percent Differ.*	(2) Percent of Rural Popula.	(2) Percent Differ.*	(3) Percent of All Non-Electr. Villages	(3) Percent Differ.*	(4) Using Both Pop and Non-Elec	(4) Percent Differ.*	(5) Percent of Total Popula.
PUNJAB	51	-19	57	-10	61	-3	87	39	51
SIND	20	100	10	80	14	45	7	-35	20
NWFP	17	13	15	3	12	-22	5	-70	17
BALUCHISTAN	10	0	6	-39	8	-18	1	-87	10
FATA	2	0	4	81	4	117	0	-80	2
	100		100		100		100		100

* Percentage difference with 1991 target outlays
(See Table 4.3-1)

(1) 90% total funds allocated on basis of total population plus 5% each to Baluchistan and NWFP.
(2) Directly proportional to rural population.
(3) Directly proportional to the number of non-electrified villages.
(4) Directly proportional to the product of rural population and the number of non-electrified villages.
(5) Prime Minister's target for 1991.

4.4 Budget Allocation II: the Provinces to the Districts (and Tehsils)

There are several reasons why the allocation of the resources for RE among the districts of a given province should explicitly reflect the relative economic and social development benefits of RE. One reason is that the Provincial Governments set much of the development policy with respect to utilization of government resources for infrastructure. Another reason is that it is easier to examine the effects of complementary investments at the district level than at the federal level because they can be more easily identified. In addition, there is more homogeneity within districts than between them; hence, social policies aimed at poor and disadvantaged groups are easier to target at the district level. (It should be borne in mind, however, that RE is not the only mechanism for income or benefit redistribution, nor is it the most efficient mechanism.)

The provincial governments may have differing relative social and/or development objectives and differing strategies on how to use rural electrification to meet these objectives. Rural electrification may be a more important complementary infrastructure investment input in certain districts due to their development potential (such as deep groundwater). In Baluchistan, for example, rural electrification is one of the key infrastructure inputs in the integrated valley development program which is a key component of the Provincial Government Development Strategy.

Reflecting these differing objectives, the provinces should allocate RE funds received from the Federal Government based upon broad indicators of expected economic and social benefits together with the costs of supply and indicators of previously low levels of RE. It is recommended that the indicators be based upon rural population size, its density, actual and potential economic activity in the district, and the current levels of RE. The specification of these indicators will require additional study and analysis. The indicators may differ amongst provinces. Unfortunately, as stated earlier (Section 3.3.2), there has been no recent quantitative ex-post analysis of electrified villages or other bases for quantitative estimation of complementary benefits.[1] Such study and analysis should be an immediate priority as discussed in Chapter 6.

4.4.1 Alternative Allocations as Examples Only

If, for example, the Provincial Government has a development objective that defines rural electrification benefits as flowing largely from the

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1. Nor have there been many detailed a priori integrated development studies which estimate total input costs and determine direct and indirect benefits and which would allow inferences of what portion of benefits might be allocated to rural electrification. For example, the integrated valley development schemes in Baluchistan have not received such detailed study.

complementarity of investments in other areas such as credit, roads, education, and overall local development potential; this should be reflected in an allocation of RE funds. An example of the allocation indices discussed could be derived from data presented in an existing 1984 study by Pasha and Hasan that has looked at this issue (Ref 45). Their study was based upon 27 indices of development obtained from readily available district statistics (see Appendix 1). Their data was drawn from all of the districts in the nation. It is recommended that a similar study be carried out at the provincial level. The advantage of the approach of Pasha and Hasan is that it reduces a complex multidimensional problem to a manageable task.

If such an index of development potential is estimated for each district within a province, then it could be used as an index of complementary investments. Table 4.4-1 shows an example of how this approach could be used to allocate the Federally supplied investment funds in the Sind. An illustrative index of complementary investments based upon the Pasha and Hasan's data was used. These data must be updated, and maybe refined, before the index could be used as a basis for actual allocation of resources. The indices should also weight the traditional concerns of the provincial governments -- "backward" rural areas, non-electrified areas, etc., with concerns for economic and social development. The table depicts three examples only of possible distributions of the RE funds to the districts of Sind. The first, shown in column 1, is a fairly traditional one based purely on rural population. The second, shown in column 2, is a 30%-70% split between rural population and the development index. Column 3 shows an allocation weighted 50% on rural population and 50% on the development index. Other rural equity concerns, such as numbers of non-electrified villages, have not been considered in this simple, illustrative example because these data were not readily available. It is important, however, to utilize measures of RE if the procedure is to be used to make actual allocations.

The table shows how sensitive the allocation procedure is to the weights on complementary inputs. For example, based upon rural population Karachi District is ranked 11th in allocated funds but a 30% weight on the development index moves it up to first place. Note, however, that Hyderabad District ranked highly in each of three cases. In other words, Karachi District has easy access to the development infrastructure but has a small rural population. Hyderabad District, on the other hand, has good access to development infrastructure and a large rural population. This looks like a very good place to implement RE under any weighting of the indices. Indeed, as a general rule-of-thumb a sensitivity analysis on the weights used in the procedure should allow the identification of districts that are good locations for investment regardless of the index weights.

The above analysis could be repeated with a weighted sum of the development index and other relevant indices of RE need such as population in non-electrified areas, or the number of non-electrified villages. Work on such allocation alternatives should involve the Provincial Governments.

TABLE 4.4-1

SENSITIVITY OF ALLOCATION TO RELATIVE WEIGHTS OF RURAL POPULATION
and
INDEX OF COMPLEMENTARY INVESTMENTS

SIND	ALLOCATION Based On Adjust I	Rank	ALLOCATION Based On Rural Pop	Rank	ALLOCATION 30% Adjust I	70% Rural Pop		Rank	ALLOCATION 50% Adjust I	50% Rural Pop		Rank
Karachi	38.58%	1	2.40%	11	11.57%	1.68%	13.25%	1	19.29%	1.20%	20.49%	1
Hyderabad	15.17%	2	11.92%	3	4.55%	8.35%	12.90%	2	7.59%	5.96%	13.55%	2
Thatta	3.29%	10	7.18%	10	0.99%	5.03%	6.01%	11	1.65%	3.59%	5.24%	10
Sanghar	6.64%	4	7.56%	9	1.99%	5.29%	7.29%	8	3.32%	3.78%	7.10%	7
Dadu	5.89%	7	9.65%	4	1.77%	6.76%	8.52%	5	2.94%	4.83%	7.77%	5
Tharparkar	7.48%	3	12.98%	2	2.24%	9.09%	11.33%	4	3.74%	6.49%	10.23%	4
Khairpur	5.03%	8	7.66%	8	1.75%	5.36%	7.11%	9	2.92%	3.83%	6.74%	8
Nawabshah	6.60%	5	14.41%	1	1.98%	10.08%	12.06%	3	3.30%	7.20%	10.50%	3
Sukkur	6.25%	6	8.13%	7	1.88%	5.69%	7.56%	7	3.13%	4.06%	7.19%	6
Larkarna	4.26%	9	9.20%	5	1.28%	6.44%	7.72%	6	2.13%	4.60%	6.73%	9
Jacobabad	0.00%	11	8.91%	6	0.00%	6.24%	6.24%	10	0.00%	4.45%	4.45%	11
Totals:	100.00%		100.00%		30.00%	70.00%	100.00%		50.00%	50.00%	100.00%	

Badin and Shikarpur not included

Source: 1981 Census Report of Sind Province.

4.5 Village Ranking and Selection: Existing Approaches to the Allocation of District Resources to Villages

Once the funds have been allocated from the Province to each district and within each district to different tehsils, the next task is how to determine the most suitable distribution of allocations for electrification of specific villages. In the past, different approaches have been used to establish a set of priorities based on:

1. distance of the villages to the existing lines;
2. ranking of the villages in the order of population;
3. ranking in the order of population to distance (from grid) ratio;
4. electrification under special donor funded projects; or
5. political prerogatives.

Each of these approaches has inherent problems as outlined below.

4.5.1 Ranking on Distance to Existing Distribution Lines

Criteria that impose restrictions on the distance of villages to the existing lines introduce a certain measure of arbitrariness in the decision making as there are no hard and fast rules as to what this distance should be. Selection on the basis of distance alone will never ensure the best financial or economic returns on capital. Furthermore, this approach excludes the option of electrifying villages which may be beyond the stipulated distance yet may offer financial/economic returns considerably higher than those villages which meet the distance criteria.

From a political viewpoint, this approach creates obvious difficulties. To circumvent this limitation, it becomes necessary to relax the distance criteria to allow electrification of certain villages. Although this solution provides the decision maker with a simple administrative or political expedient for selection of villages within the defined boundaries, the requirements of financial and economic viability become even more difficult to meet as cost effective but interdependent electrification options are restricted (i.e. a joint electrification of adjacent village inside and outside of the distance criterion).

A single "distance to line" limit is not desirable even from the interprovincial perspective. Without any restrictions on minimum returns to capital invested, the distance-to-line approach may result in selection of villages which may not offer the best financial and economic returns. Wasteful use of resources will reduce the number of villages which could be electrified if the resources were more efficiently allocated.

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As villages are electrified using the limited distance criteria, the incremental expansion of the networks does not allow the planned development of the networks based on (1) the best possible technical design of the network configuration and (2) maximizing returns on investment which may require electrification of villages beyond the distance limits. On the other hand, the distance-to-line approach essentially leads to a progressive development of the network which may be perceived as equitable by the rural population, since everybody within the designated distance-to-line range has the same priority. Those who are outside the range have to wait their turn.

Although this approach is simple and incorporates some social considerations, it is not equitable either to individual large villages beyond the distance limit or to groups of settlements within the distance-to-line limits as each individual village or settlement within the distance limit is treated on its own. Since only census data and villages have been used, only villages in the census reports become eligible for electrification. Small settlements, which the form of groups may be more viable than individual villages, may not fit in this selection methodology.

4.5.2 Ranking in the Order of Population Size

Within the criteria of the distance to the existing distribution lines, the villages are ranked in the order of their population size. Quite often this method gives good economic returns in case of limited distances (such as 0.5 mile or 0.8 km) since the cost of distribution line is relatively small with respect to the cost of distribution system within the village.

Ranking only in the order of population size without reference to or limit on the distance to the line is not recommended. This approach fails to address the costs of RE and consequently ignores return on capital.

4.5.3 Ranking on Population to Distance Ratios

The use of the population to distance (P/D) ratio for village ranking has several drawbacks. The most important one, common to many criteria, is that it examines each village in isolation and ignores its relative proximity to other villages. RE is most cost effective on an area basis, and the RE benefit-cost ratio and return on capital are both a function of the RE of a group of interdependent villages. While the village specific P/D ratio may be a proxy for a benefit-cost measure, it has little correlation with the B/C ratio for the group of villages electrified in a project. Still, it is possible that the P/D ratio for groups (or clusters) of settlements or villages will result in rankings which are similar to the rankings based on a more rigorous economic and technical analysis of the groups. The difference is in the definition of distance: the distance "D" for a group or cluster of villages is totally different from the "D" for an individual village. Furthermore, the distance must be measured along the least-cost distribution line, rather than the straight-line distance between points. To estimate the distance for a group of villages requires a detailed analysis similar to that presented in section 4.6 below.

Further examination of the use of population to distance ratios is most easily done by reviewing the two components of this ratio separately. The use of population size as a proxy for benefits may be applicable in areas where the structures and nature of the villages are homogeneous and the electrification of tubewells is ignored. The discussion in chapter 3 indicates that benefits are a function of relative mix of industry, tubewells and households. However, in all rural areas, the number of small industries varies from one village to another. The same is true of commercial activity. While some villages may have a large number of shops because of their status as market centers, others with the same population/distance ratio may not have these amenities to the same extent. Similarly, in many districts large concentrations of tubewells may be found as a function of differential groundwater availability. Another important element in this calculation is the mix of low, average and high income households. Since the ultimate benefits from the electrification of a village are a function of the customer mix within the village and the number of tubewells around the village, population size alone is not the best way to estimate RE economic benefits.

The conclusion that population is not the best estimate of benefits must be tempered by the data requirements of creating a more accurate estimation procedure. Without information on other customer populations or on the varying relationships between population and the numbers of other customer types, population may remain as the best available measure. As is discussed below, further studies to improve the benefit measure are strongly recommended. However, it may be necessary to use population size in the short run in order not to delay the ongoing RE process until the results of the further studies are available. The incorporation of the results of these further studies should consider the trade-off between the value of increased accuracy and the cost of additional data requirements.

The cost side proxy of the P/D ratio - distance - is even more problematic. As discussed above, a distance from the grid measures does not capture the cost of electrifying a specific village. This cost is more a function of the village's location relative to other villages, and the size of the other villages, than the village's present distance from the grid. As is discussed below in the suggested procedure section, the cost side must be captured by examining the relative location of the village with respect to surrounding villages as well as the grid.

4.5.4 Electrification of Village Under Special Donor Funded Projects

Integrated tubewell and rural electrification projects are being planned within the WAPDA System. An example is the Salinity Control and Reclamation Projects (SCARP) where the distribution system was constructed primarily for electrification of SCARP tubewells, but provision was made to electrify villages through extensions of these lines. Normally, the cost of village electrification under these projects is not included in the project cost. The nature of these projects requires a different approach to selection of villages, as it is the SCARP tubewells locations which dictate the routes of the lines, and electrification of villages becomes a secondary objective.

As the network configuration is well defined, possible extensions of the lines to electrify villages can be determined on the basis of the available detailed design of these networks. The ranking of villages, thereafter, can be done on the basis of best returns on investment.

4.5.5 Political Prerogatives

While many villages have been selected on the basis of a well-defined methodology, a certain number of villages have been electrified on the basis of political preferences of the people's representatives (members of Provincial and National Assemblies and Senators). In the future, the electrification of such villages should be financed from special funds of the provincial or federal government. As the villages were selected on purely political grounds, there has been little accounting of the often long distances, the high capital costs, and the resulting low return on capital.

It is difficult to attain a balance between a highly restrictive economic return approach and the political considerations which dictate selection of certain village in accordance with the wishes of the political representatives. However, if the emphasis in rural electrification could be shifted from the number of villages electrified to the number of beneficiaries, the political selection process can come much closer to the economic return approach which aims to minimize the cost of capital per customer through increases in the number of beneficiaries.

4.5.6 Ranking by Economic Internal Rate of Return (EIRR)

The application of a minimum economic internal rate of return (10%) was done under the ADB Sponsored Rural Electrification Project (Ref 89) in Pakistan. Candidate villages were ranked in descending order of their rate of return.

The villages with the highest rates of return were selected based on the available budget. This selection methodology was based on data from field surveys for the quantification of direct benefits from rural electrification. For each village, a rate of return calculation was made on the basis of demand, benefit, and cost forecasts for a period of 30 years. The method of calculating the rate of return required extensive field surveys and computations. It is possible that less sophisticated but quicker calculation procedures based on simplified financial and economic analysis methodology may have been able to provide the same answers at a much reduced cost and within a much shorter time period.

Although from a conceptual and methodology viewpoint, the EIRR calculations are standard in project analysis, the ADB analysis had some defects. The ADB RE Project only covered villages which could be electrified from existing lines and only one solution for connection of the village to the line was considered. This is a major limitation of the approach in that the most economic (or least cost) connections were not found because villages were examined individually and not as groups. The relative location of the village to other villages was not considered.

4.6 Village Ranking and Selection: Proposed Approach

4.6.1 Overview of Village Selection and Implementation Process

Based on the above discussion, a new methodology is required that satisfies, to the extent possible, the following criteria:

- Captures the location of the village/settlement relative to both the grid and other villages/settlements;
- Reduces the risk that any particular village will only be electrified only after other adjacent villages are electrified;
- Includes villages that are beyond an arbitrary distance from the feeder
- Incorporates measures of economic and financial benefits and costs;
- Represents the best possible design of the network given long-range planning objectives;
- Requires only data that are already available or easily collected;
- Can include more detailed demand or benefit information when available such as household income distribution, numbers of rural industries, tubewells and other non-household customers as separate parameters;
- Uses technical and cost parameters that are project-specific;
- Is relatively straightforward and simple to implement; and
- Can incorporate decentralized generation options.

In addition, the methodology must be practical and entail a relationship between several groups of economists and engineers who play a role in the ranking and selection process. The possible players in this process are engineers at the REO, the AEB and the provinces and economists/planners at the REO and the provinces. Their roles should optimize the use of their varied experiences and skills. A number of different options are possible. The one ultimately used must evolve based on discussions and preliminary work between WAPDA and the provinces.

One option is that initially engineers and economists of the REO working with the AEBs develop the village rankings and the REO presents them to the provinces. The ranking work could eventually be transferred to the AEBs with some basic assistance from the REO economists. Alternatively, the economists from the provinces could do the rankings based on WAPDA cost data and the REO assists in benefit estimation. In any case, the ranking procedure should be applied the above criteria to the following village-specific data:

- Numbers of tubewells, and small industries, and other customer classes
- Number of households (and possibly income distribution);
- Connection, wiring, tariff, and other customer costs;
- Applicable generation, transmission, grid station, transformer, O&M, and other system costs;
- Overall least cost distribution expansion plan for total electrification;
- Location relative to other villages and the grid;
- Expected electricity usage (kwh), demand (kw) and peak coincidence (diversity) factors for each customer type: and
- Growth rates of each customer type.

The data base for village ranking and selection will be maintained by WAPDA REO at headquarters and AEBs. The candidate villages will be the main villages and all settlements. WAPDA shall submit to the provinces the updated lists of all villages and settlements. The provinces shall then indicate which villages and settlements have not been included in the master data base. The provinces may also provide WAPDA REO lists of settlements and villages which are to be included in WAPDA REO's data base.

Using this comprehensive list of candidate villages, the selection methodology, the b sic parameters for evaluation of benefits and costs, and the budget constraints will generate a list of villages which fulfills the requirements of village selection criteria and other constraints. The list of selected villages will be finalized and approved by the provinces.

It is understood here that the basic parameters for benefits and cost estimation would be updated by WAPDA REO on the basis of sample surveys to be carried out on an annual basis in different parts of each province. It is also understood that WAPDA REO will maintain a set of as-built maps of the existing system along with base maps showing locations of main villages and settlements. The distribution expansion plans shall also be reviewed and updated on an annual basis by WAPDA's rural electrification office at headquarters.

Once the villages have been selected using the selection methodology described here, the next task will be to determine the least cost distribution expansion plan for their electrification. For this purpose, the Work Order System will be utilized. Under the Work Order System, first of all a Planning Proposals (covering technical analysis of different technical solutions and selection of the most suitable alternative) will be prepared. Once the Planning Proposals have been approved, a Job Order (or other appropriate mechanism) covering field surveys and detailed engineering for distribution construction will be prepared. The Planning Proposals as well as the Job Orders shall be prepared by the AEBs. Initially, the WAPDA REO at the headquarters may take responsibility for generation of both the planning proposals and the Job Orders, but as soon as the AEB REO Organization is in place, this work shall be done by the AEB REO Office.

In order to meet the above criteria, a benefit-cost (B/C) analysis is suggested. However, this suggested B/C criterion is different from the other measures described above in that, for a given village, it is a function of the benefits and costs for nearby villages. The B/C ratio can be conceptualized as applying to a group of villages. This resulting B/C ratio would be the composite criterion for the primary ranking of villages.

The methods suggested below, though developed so that they can be performed with some training by WAPDA staff, are not as simple as some of the existing ones discussed above in Section 4.5. While the benefits side can be estimated in different ways starting with some very simple data in the short run, all benefits must be examined in the context of those of nearby villages. Furthermore, the cost side cannot be estimated easily without technical analysis to approximate the least cost distribution network for central grid and decentralized generation options.

Before the village selection process is started, it is important for the utility (WAPDA) to have at its disposal a least cost distribution expansion plan for total electrification of the areas under consideration. In particular, questions relating to the transmission network orientation, locations and types of grid stations, choice of primary distribution voltage, phase options and the network configuration of the proposed feeders must have been resolved. Maps showing locations of villages, grid stations and least cost feeder configuration of the proposed network expansion must be available. These maps must also show all the existing distribution lines and electrified villages. Parallel to these maps, a village data base covering basic demographic data (population, households, acreage, etc.) is also required.

Using the information outlined above, the different alternatives for village electrification can be developed. In both cases, the optimal technical solution should be kept in view and the possible extension of lines to a new village to be electrified must include the expansion alternatives under the least cost technical solution.

To understand the issues involved in ranking villages, a number of case studies of village and tubewell electrification were carried out in one area in each province:

1. Punjab : District Okara, Tehsil Okara
2. Sind : District Thatta, Tehsil Thatta
3. NWFP : District Bannu, Tehsil Lakki Marwat
4. Baluchistan : District Kalat, Tehsil Kalat

A limited number of villages were included in each case study. Further work is needed to select and refine one method for the next phase of village selection.

Three methods are presented that embody the suggested approach. A brief description of each is given below; in the next section, an example of each method for the set of villages in the four provinces is given. For ease of discussion these methods are called (1) the Cluster Method, (2) incremental B/C ratio methods, and (3) the cumulative B/C ratio method. Some of the examples presented focus on one or more of these methods. The purpose of these examples is to demonstrate these methods in a variety of settings.

4.6.2 The Cluster Method

For the sake of further explanation of this approach, a simplified method for estimating these B/C ratios could be imagined which uses a least cost expansion plan for the complete electrification of a district and then estimates the benefits and costs for each grid substation feeder. Each feeder could then be ranked based on the resulting B/C ratio. The ranking of villages in the district would be in clusters based on the ranking of feeders; villages would be electrified in clusters. The main problem with this simplification is that it only considers complete electrification of feeders without the option for partial electrification. The methods discussed below present ways to consider partial and/or complete electrification in the ranking of villages while still analyzing their attractiveness in the context of surrounding villages.

Extending this procedure to incorporate clusters of villages does incorporate these additional issues. Clusters of villages and/or tubewell load centers are formed and the number of village investment alternatives is reduced to the number of clusters.

This method in combination with the best technical solution to electrify the villages, can provide a fast algorithm for ranking villages. With a large number of possible cluster formations however, the selected clusters may not offer the optimal solution. A computer based mathematical programming algorithm, which examines all possible alternatives and generates the optimal solution, would be required and can be developed. However, judgmental work may be able to determine a solution which is not substantially sub-optimal.

4.6.3 Incremental Benefit - Cost Ratio Method

Selection of a certain number of villages during a particular stage of RE is dependent upon the available budget. The highest ranked villages are selected in descending order of the B/C ratio (BCR). Villages which are selected generate new dependent solutions; selected villages become the starting point for electrifying other villages. The un-selected villages are again ranked with the additional possibility of being selected based on lines from nearby selected villages (or what can be called new dependent solutions).

The basis for this set of methods is the increment in benefits and costs from any given point on the distribution system to the next point or points. The option selected represents the highest B/C ratio available at the time.

This in fact represents a large group of methods, depending upon the method used to estimate the costs and benefits of a single distribution line: whether these costs and benefits are only for the one village that is connected using this line, the next two villages, or for all potential villages that could some day be electrified farther along this distribution line.

Including only the costs and benefits of the next connected village is a very simple procedure to implement. This is called the "Marginal Incremental" method. It requires the computation of benefits and costs only one time, and the investment choices are then clear. The main disadvantage, however, is that a distribution line may be postponed indefinitely even if a village with extremely high potential benefits is one village beyond any that is under consideration.

At the other extreme to the Marginal Incremental method is the Total Incremental method. Using this procedure, the costs and benefits for electrifying all of the villages on a distribution line are included in the B/C ratio for any single investment choice. Thus the choice to build a particular distribution line will incorporate the benefits and costs of all future possible villages that can be electrified as extensions of that line.

The Total Incremental method has one of the advantages of the Marginal Incremental method: it requires the computation of the benefits and costs only one time. However, it does require the creation of "fictive" points, which are branches in the distribution line where no village exists. These represent decision points, with B/C ratios associated with each branch. Each investment decision involves the construction of a line to the next village or to a fictive point. This method is slightly more complex than the Marginal Incremental method, but it does have the advantage of accounting for the benefits and costs of all future villages to be electrified.

It is conceptually feasible to consider procedures that look ahead to two, three, or any other number of villages along the same distribution line when computing the B/C ratio at a fictive point or a village. The main disadvantage to any of these intermediate methods is that they all require the re-computation of the benefits and costs for all villages along a distribution

[illegible] of the villages will therefore be cumbersome and difficult to implement. For this reason, on the Marginal Incremental and Total Incremental methods will be examined here in detail.

This incorporates most of the criteria for an improvement over previous methods. However, this may at first exclude villages far from the feeder, and may in fact not represent the optimal design from a long-term planning perspective.

4.6. Cumulative Benefit - Cost Ratio Method

Based on the least cost distribution network for complete electrification, the cumulative B/C ratio for each village is computed as the sum of benefits divided by the sum of costs of all villages on the same feeder up to that village. Since this cumulative ratio is calculated at each point along the feeder, one can capture the attractiveness of continuing electrification along the feeder.

The villages are then ranked according to this cumulative B/C ratio. This ranking is then adjusted to take into account the fact that the electrification of some villages is dependent on the electrification of other villages that are lower on the list. These villages with low B/C ratios are then ranked up with the higher B/C village. The selection of villages then depends on the budget available starting at the top of the list. In this way if funds are not available to electrify complete feeders, the villages with the highest B/C ratios overall are electrified.

4.6.5 General Observations on the Ranking Methods

The above methods, while all requiring the same basic data and all capturing the recommended general approach, have differing advantages and disadvantages. Furthermore, these advantages and disadvantages depend on various aspects of how RE ranking and implementation will occur. Consequently, the choice of method or variant is also dependent on these RE aspects.

One aspect is the level of complexity of calculation of the data for village ranking and this in turn is dependent on who and what group(s) will perform the calculations. A second aspect is the pace of RE in terms of what the national budget translates into on the district or tehsil level in terms of numbers of villages electrified in what period of time. For example, will there only be sufficient budget for only one or two villages off of one grid substation to be electrified in one year? Furthermore, will several villages be electrified each year or will electrification occur in groups every five or more years? A third aspect is the politically and socially acceptable pattern: can whole feeders be electrified at one time whereas others are not or must electrification be spread out more evenly? And the last aspect is to evaluate the loss or gain of benefits for a given budget by choosing one method versus another.

In terms of complexity, there are two types: (1) the recalculation of the BCRs as villages are ranked because the ranking of nearby villages affects other villages BCRs and (2) re-examination of which villages are available for ranking because nearby villages are ranked. Whereas such recalculation and re-examination might improve the economic benefits which can be captured within a given budget, some sort of computerized procedure would be needed to undertake them for a large number of villages. In turn the computerization of this approach is dependent on whether the ranking process will be centralized in the proposed REO or in the provincial government headquarters or decentralized in the AEBs. For example, the incremental BCR methods involve continual re-examination of the village electrification options. The cumulative BCR method does not involve either of these complexities, but its performance can be improved by doing a recalculation. The cluster method also does not involve either complexity.

The pace and the acceptable pattern of electrification affects the number and geographic spread of villages to be ranked. If the RE budget is very limited a broad pattern of electrification is desired, the marginal incremental method could be useful whereas the cluster method may lead to the concentration of electrification in a few areas. The cumulative method permits ranking of the most attractive part of an entire feeder rather than being locked into doing entire feeders at once. The pace of electrification also affects the penalties in terms of lost benefits from a non-optimal ranking. For example, if electrification was proceeding at a very rapid level such that a village not electrified one year would be electrified within the next year or two, then the penalty for an uneconomic ranking is less. On the other hand, if electrification is quite slow, the penalty can become large.

In some of the case studies presented in the next section, these aspects are discussed in the context of examining some of the advantages and disadvantages of these different methods. In the end, the choice of method will depend on the answers to such questions as who is doing the calculations and ranking, what are the budget levels and time periods, and what are acceptable electrification patterns.

4.7 Data Requirements for the Proposed Ranking Approach

There are three basic categories of data needed to apply this approach: (i) benefits and demand, (ii) costs, and (iii) distribution plan. The basic data used in these illustrative examples of the different methods of applying our recommended approach are presented in Table 4.7-1. At present much of the data have to be estimated. Detailed work on development of a comprehensive data base for selection methodology must be initiated (see Chapter 6).

TABLE 4.7-1

BASIC DATA FOR VILLAGE RANKING EXAMPLES

	HOUSEHOLDS					
	LOW INCOME	AVERAGE INCOME	HIGH INCOME	COMMERCIAL	INDUSTRY	TUBEWELLS
A. PRESENT VALUE BENEFITS						
- Gross Benefits/Customer (Rs/y)	525	787 *	1882 *	700	21760	16800
- Net Present Value of Benefits (Rs) (10% discount rate)	5250	7870	18820	7000	217600	168000
- Estimated Usage (kWh/Yr)	240	540	1800	540	12800	8300
B. PRESENT VALUE OF CONNECTION AND VILLAGE COSTS						
- Peak kW per Customer at Distribution Transformer	0.22	0.47	1.31	0.39	16.74	10.85
- Peak Coincidence Factors:						
at generation	0.65	0.65	0.65	0.65	0.65	0.65
at grid substation	0.75	0.75	0.75	0.75	0.75	0.75
at distribution transformer	0.85	0.85	0.85	0.85	0.85	0.85
- Capital Cost						
a. Connection Cost Rs.	840	840	840	840	6300	28175
b. Village Distribution Cost @ 1750/kW Rs.	385	823	2293	683	29295	-
- Present Value of Costs (incl. 5% of capital for annual O&M)	1840	2490	4700	2280	53390	42260
C. COST HT DISTRIBUTION LINE: 70,000 RS/KM						

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* Although these benefits estimates were used in the ranking exercise, they were subsequently revised after the ranking exercise was completed. The newer estimates, which are presented in Chapter 3, are 990 Rs. for average income and 2889 Rs. for high income households.

4.7.1 Benefits and Demand Data

The basic benefit and demand data are the following for each customer category included in the analysis: benefits per year, kwh consumed per year, kw peak demand, and peak coincidence or diversity factor. Additional data could include the growth of kwh use over time, the penetration or customer saturation rate over time, and the growth of each customer class over time. In the examples presented below, the latter set of data were not used, but the analysis could easily be extended to include them. The village analysis presented in Chapter 3 and in Appendix G is based on computer analysis that does incorporate these data.

On the other hand, the present values of benefits that are used in the case studies below are based on the assumption that the demand levels (and their corresponding benefits) that would be attained in the tenth year of electrification are associated with every year of the analysis, starting with the first year. It is also assumed that there is a 100 percent penetration of all households the first year. Since all villages are treated in a like manner, such simplifying assumptions do not alter their rankings. It is possible to base the value of benefits on gradually increasing electricity use levels.

The benefits estimate can be based on many different levels of analysis depending on the availability of information. In the previous chapter the difficulties associated with benefits estimation were discussed. Benefits partially depend upon whether one views rural electrification as a complementary rural development investment or as a self-contained directly productive investment; RE has attributes of both. In preparing this master plan, initial estimates of the direct benefits have been calculated. Complementary and indirect benefit measurement was not feasible given the shortcomings of the current information base. As presented in Chapter 6, additional studies are needed to determine what if any benefits due to complementary investments issues are justifiable (and measurable). In addition, such future work should also examine how the benefit and related estimates presented here vary from region to region.

Another benefits issue is the incorporation of social and political goals and policies such as the promotion of a more equitable distribution of income. This could be achieved by using "social weights" in the calculations to increase the benefits of one class such as low income households. The examples below do not include such weights though they could easily be introduced. One final benefits issue is the development of benefit estimations tailored to a specific region; there was not sufficient data to warrant such work for this plan, but future efforts should incorporate these variations.

In this example, the village benefits are a function of the number of households of different income classes, rural industries, tubewells, and commercial establishments. Reviewing several of the RE District Master Plans (Refs 150, 160, 161 and others) and using the village model from Chapter 3, households accounted for roughly 50 to 80 percent of total benefits, industry and tubewells each accounted for between 5 and 25 percent, and commercial for 3 to 10 percent. Since household benefits constitute the largest share and the benefits vary substantially by income class, the analysis in Chapter 3 examined different income classes. However, in these examples and likely in the initial applications of this approach, income classes will not be used because of the lack of and difficulty in obtaining the needed data. Future studies will have to examine how and if income class detail can be incorporated into the benefits estimation. Furthermore, as was mentioned above, if necessary due to the lack of data, the next round of village selection can be based on only population until the needed data base is developed.

For example, the benefit, demand, and cost estimates for the average income household presented in this report could be used with the village population (assuming an average household size) to estimate village household benefits, demand, and costs. Household benefits could be increased by 10 to 20 percent for an estimate of the total village benefits (excluding tubewells) for villages with fewer than 100 households, and by 50 percent for villages with more than 100 households in order to capture the inceased demand due to industrial and commercial customers.

The procedure for the estimation of benefits will evolve over time as more data become available and analysis indicates the value of including more detail. It is important to consider the sensitivity of this approach to the level of benefit estimation detail. Since this part of the allocation process addresses the ranking of villages within a district or tehsil, most distortions will occur only within this area. Therefore, they will be less significant than if villages were being compared throughout the province or country. At this level, other possible distortions are also minimized. For example, if electricity is viewed as part of the rural development scheme in a district, funds for RE might be forthcoming based on the development potential index suggested above for the allocation of RE funds to the district/tehsil level.

4.7.2 Cost Data

The cost data needed for the examples below are for the customer connection, village distribution (LT line and transformers), and area distribution (HT lines). For ease of calculation, the B/C ratios developed below do not include generation and transmission because these costs will be nearly the same for all customers and villages, and nearly all of the cost variations are covered by the RE costs. Due to this simplification, it is important to note that these B/C ratios do not reflect the true economic viability of these investments, but rather the relative ranking among them. As discussed below in Chapter 5, B/C ratios which include generation and transmission will be needed in the comparison of central grid versus decentralized generation options.

4.7.3 Distribution Plans

Before the village selection process is started, it is important for the utility (WAPDA) to have at its disposal a least cost distribution expansion plan for total electrification of the areas under consideration. In particular, questions relating to the transmission network orientation, locations and types of grid stations, choice of primary distribution voltage, phase options and the network configuration of the proposed feeders must have been resolved Maps showing locations of villages, grid stations and least cost feeder configuration of the proposed network expansion must be available. These maps must also show all the existing distribution lines and electrified villages. When performing the village ranking, the optimal technical solution should be kept in view and the possible extension of lines to new villages must include the expansion alternatives under the least cost technical solution.

Given that a substantial proportion of the rural population may be beyond reach of the central grid for many years to come (Ref 32), electrification plans incorporating decentralized generation options are also needed. The basic analysis that is required involves the identification of villages that would be most economically electrified from decentralized sources; a brief discussion of this analysis is presented in Section 5.3. This supporting technical analysis would also include approximate generation costs and identification of any "mini-grids" connecting groups of nearby villages.

The use of renewable energy sources for electricity in villages that would otherwise be served by the central grid must be evaluated by a comparison with the costs of electricity delivered by the grid to that village. If the renewable source compares favorably, a further analysis should explore the ease with which this renewable source can be integrated with the grid at a future date.

4.7.4 Benefit and Cost Calculations

The first part of the analysis is to calculate the the benefits for a village after subtracting customer connection and village distribution costs. The benefits and costs used are net present values (NPV) over a 30 year period. (In these examples for ease of calculation, the benefits and costs are not varied by year; therefore, the present value of a stream of equal annual amounts can be estimated as the annual amount divided by the discount rate of 10 percent.) First, the actual NPV of benefits for each customer type is the NPV of gross benefits less the NPV of the connection cost and of the customer's share of village distribution costs (calculated as the customer peak demand at the distribution transformer times the the unit distribution cost). These costs include the NPV of the O&M costs. Second, the NPV for each customer type is multiplied by the number of potential customers of each type, and summed to estimate the total benefits for a village or cluster tubewells. In these examples 100 percent customer saturation are used.

It is this village benefit estimate along with the HT line costs (for connecting the villages) that are used to form the B/C ratios used in the village ranking methods illustrated below.

4.8 Illustrative Examples of Proposed Ranking Approach

A number of case studies were prepared to present the BCR ranking approach. The examples focus on non-electrified areas. Applications of the ranking methods for villages only are presented below.

4.8.1 Punjab: District Okara, Tehsil Okara

Example of the Marginal Incremental B/C Ratio Method

The following illustration is based on a sample of 16 villages in tehsil Okara, district Okara (Fig. 4.0). The electrification of these villages is completed in five stages which represent consecutive budget periods. This approach could include tubewells in the set of options as well, each with its own BCR. They have not been included here for the sake of simplicity.

This approach requires that the least cost distribution network has been designed. Clusters of villages are established, and these clusters are rank ordered by their composite BCRs If the budget is large enough to allow electrification of entire clusters, then this ranking guides the order of selection of these clusters for electrification. If, as in this example, the budget is much more limited, then individual villages are considered on the bases of their individual incremental BCRs The BCRs for all of the villages within the clusters are computed, and villages are selected according to their BCR rank order for electrification, subject to technical distribution constraints, until the budget constraint is reached.

An independent option is a village that can be electrified from the existing grid. A dependent option is a village that is best electrified after other villages nearby are electrified first. A first order dependent solution is a village that is best electrified after only one other; a second order dependent solution is a village that is best electrified only after two other villages are electrified, and so on. In this example, in each phase, as a rule only independent and first order dependant options are considered. In other words, villages whose electrification would require the electrification of two or more villages before it on the distribution network are not considered. This simplification provides an algorithm which is relatively simple to present, and yet allows the process to consider villages farther removed from the existing distribution network. This rule could be relaxed such that second order dependent options are considered; this would capture more of the cluster issue but makes the presentation more complex. The cumulative B/C method example presented below considers more of these dependent options.

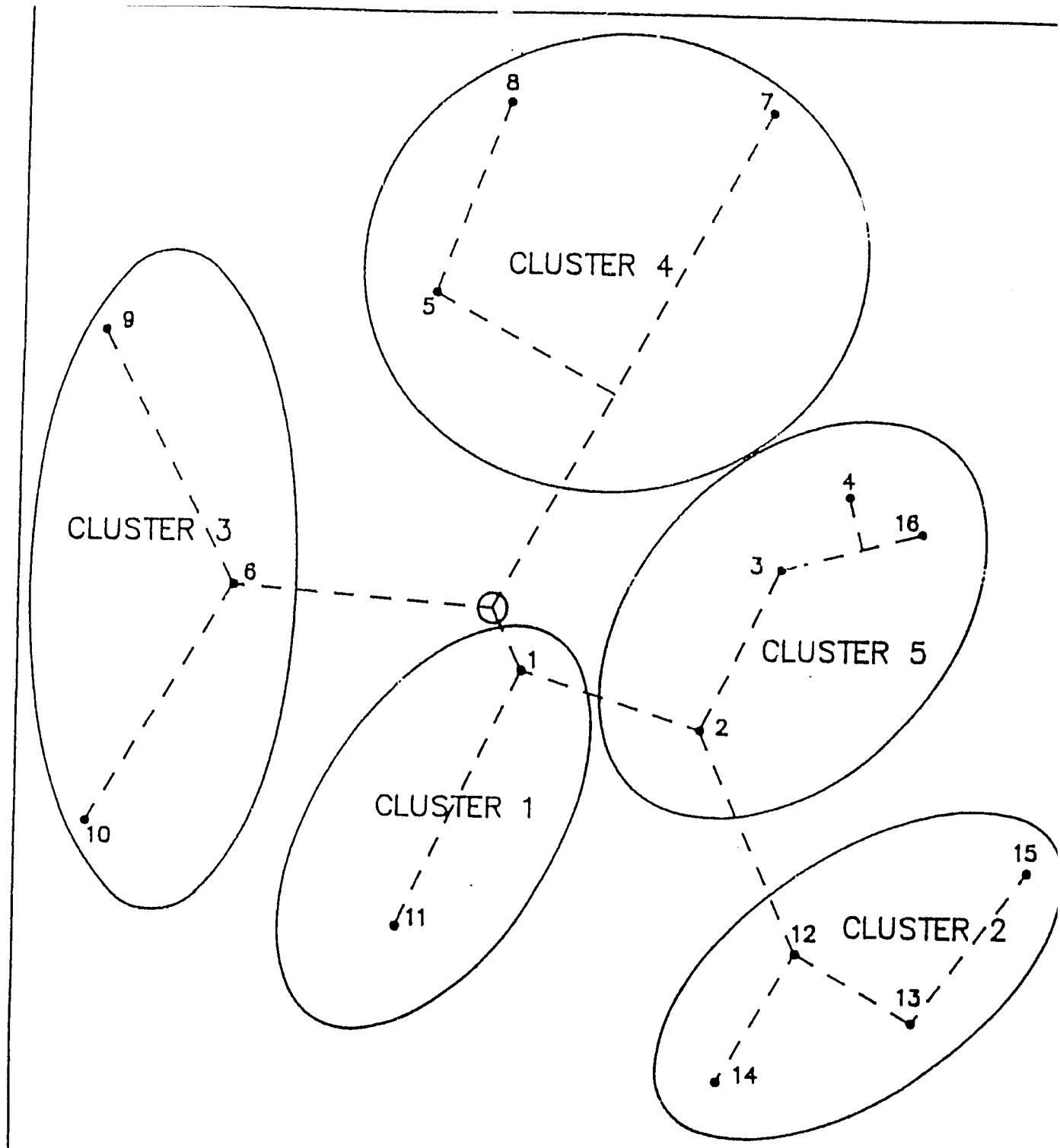

FIG. 4.0 Sample area, Tehsil Okara
Showing optimal technical solution and clusters.

In subsequent stages, the process of selection proceeds by BCR rank order given the new locations of feeders from prior stages, and subject to the budget for that stage, as well as to the technical constraints, until electrification is complete.

The following is an example of the application of this procedure, using five budget periods:

Stage (Period) 1

In the first stage, clusters of villages were formed based on consideration of the long-run, least cost, technical network, as shown in Figure 4.0 and listed below:

Cluster 1: Villages 1 & 11

Cluster 2: Villages 12, 13, 14, 15

Cluster 3: Villages 6, 9, 10

Cluster 4: Village 7, 5 & 8

Cluster 5: Villages 2, 3, 4, 16

Then, the incremental BCRs for all of the individual villages are computed. The BCRs for the villages in this example are as follows:

Village #	BCR	Village #	BCR
1	1.433	9	1.335
2	1.365	10	1.271
3	1.324	11	1.376
4	1.437	12	1.343
5	1.398	13	1.410
6	1.380	14	1.405
7	1.364	15	1.375
8	1.293	16	1.389

Next, the villages are ranked by BCR. Starting with the top-ranked village, they are electrified until the budget constraint is reached.

In this example (Figure 4.1), villages 1, 6, and 11 were selected to be electrified before the budget was exhausted for this period. Number 1 was selected first as it was the independent option with the highest BCR.

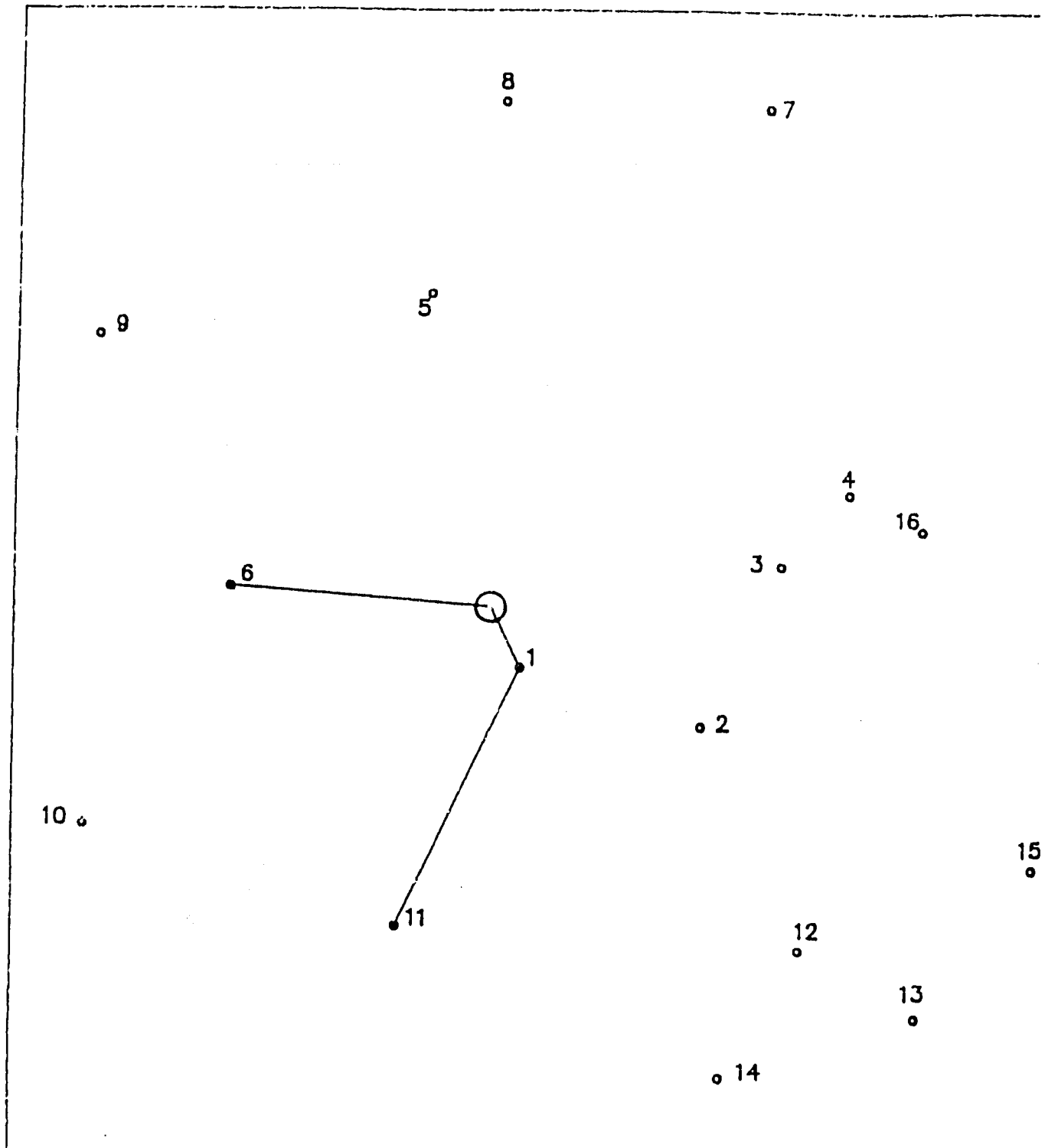

FIG. 4.1 STAGE 1 : Budget allows electrification of villages 1, 6 and 11

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Having selected #1, numbers 2, 11, 7, and 6 can be electrified. Among these 6 has the highest BCR and was therefore selected for electrification next. Following our simplifying rule (above), composites of 2+12 or 2+3 were not considered, nor would 12 alone be considered had 2 been selected in this stage. The Cumulative B/C Ratio Method discussed below would allow consideration of villages farther along the planned distribution feeder lines.

Stage 2 (Figure 4.2)

The village connections under stage 1 provided independent options for electrification in stage 2 of villages 2, 7, 9, 10, and 1st order dependant options 5, 3, and 12. From these, first #2 was selected since it had the highest BCR of the remaining unelectrified options. Then #7, and finally dependent option #5 were chosen before the budget for the period was entirely allocated.

Stages 3, 4, and 5 (Figures 4.3-4.5)

In the three stages following Stage 2, the same algorithm was applied with budget constraints for each period until the entire tehsil was electrified.

This approach assumes that there will be sufficient budget to complete the electrification process in the short to medium term. If this assumption is not true and RE funds may be available only after long intervals, then an alternative approach should be used which considers all villages within the planning area independently and in clusters. The long-run, least cost technical solution would be used not as a constraint, but rather as a guide to judgement, and the electrification plan would be redone after each new budget allocation as if it were the final period. This approach, however, may produce a sub-optimal solution in the long run if sufficient funds for completion were to become available in a shorter period of time. On the other hand, there may be cost savings by avoiding line construction based on expected electrification that does not occur for many years.

Example of Cumulative Benefit - Cost Ratio Method

This method explicitly assumes that a long-term technical least cost distribution network among villages has already been designed, that locates all lines for villages to be electrified. Based on this least cost network, the cumulative B/C ratio for each village is the sum of the benefits and costs of all villages on the same distribution line up to that village. Table 4.8-1 presents some of the basic data. The villages are then ranked according to this B/C ratio, as shown in Table 4.8-2.

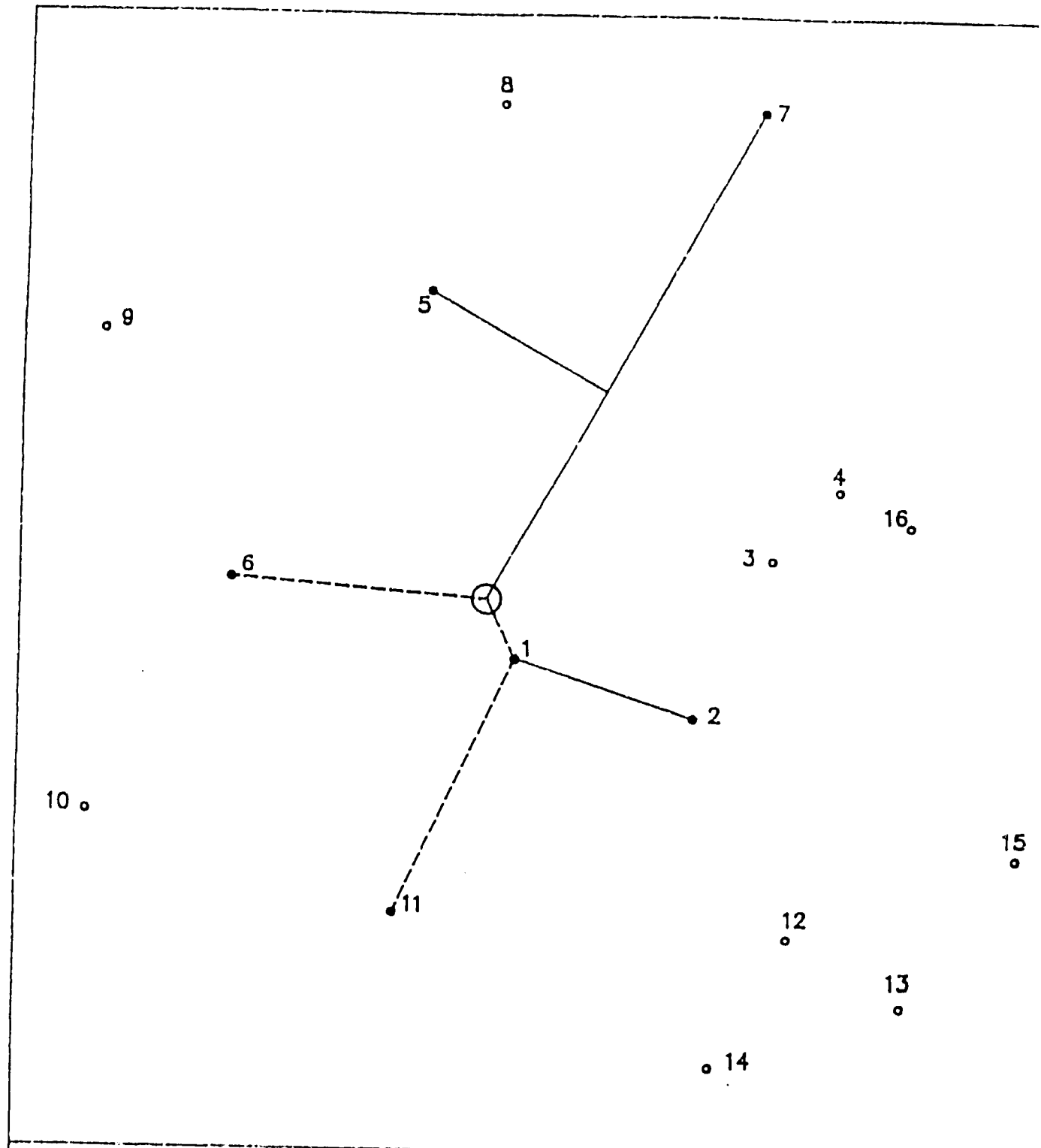

FIG. 4.2 STAGE 2 : Budget allows electrifiction of villages 2, 5 and 7

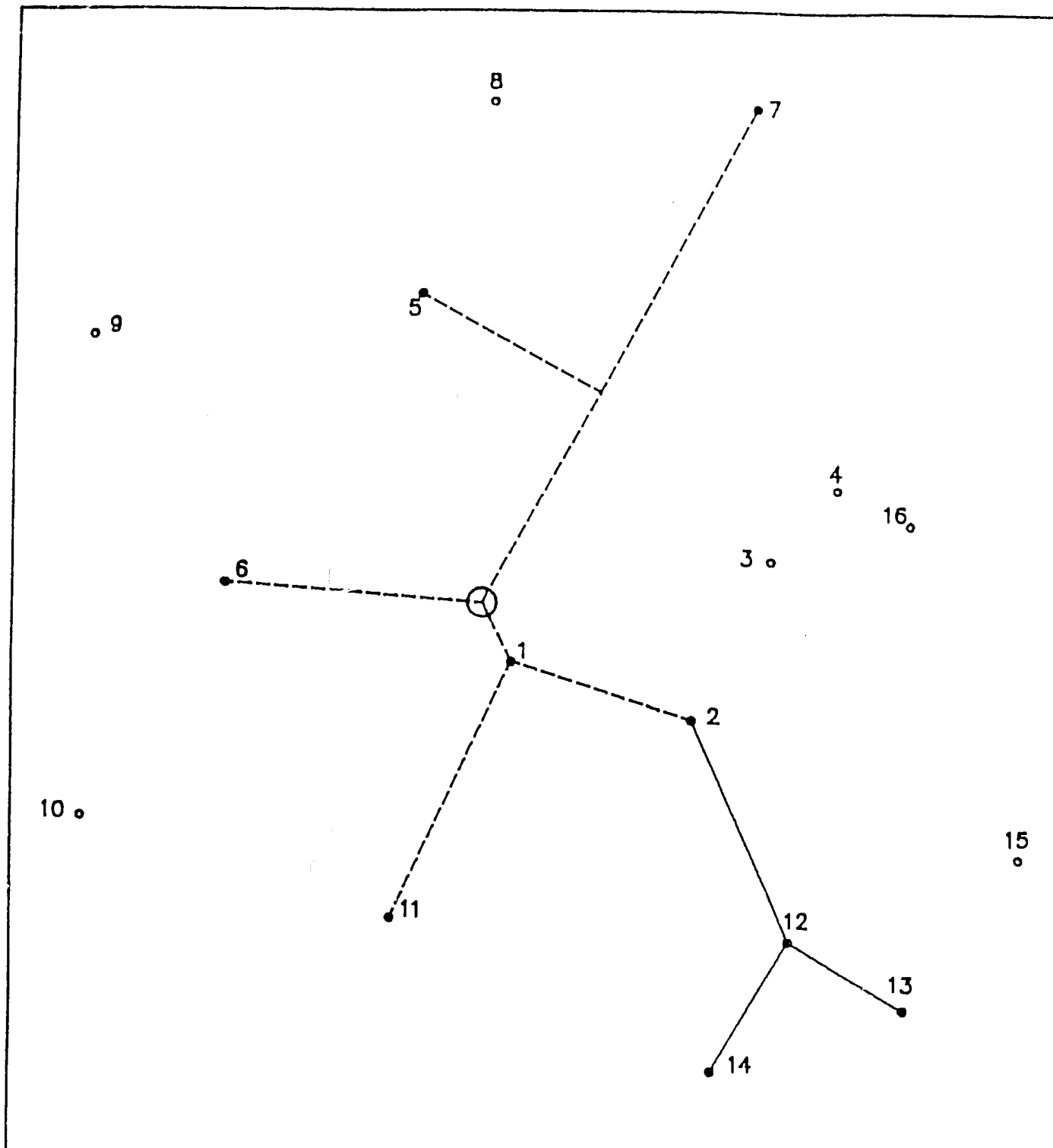

FIG. 4.3 STAGE 3 : Budget allows electrification of villages 12, 13 and 14

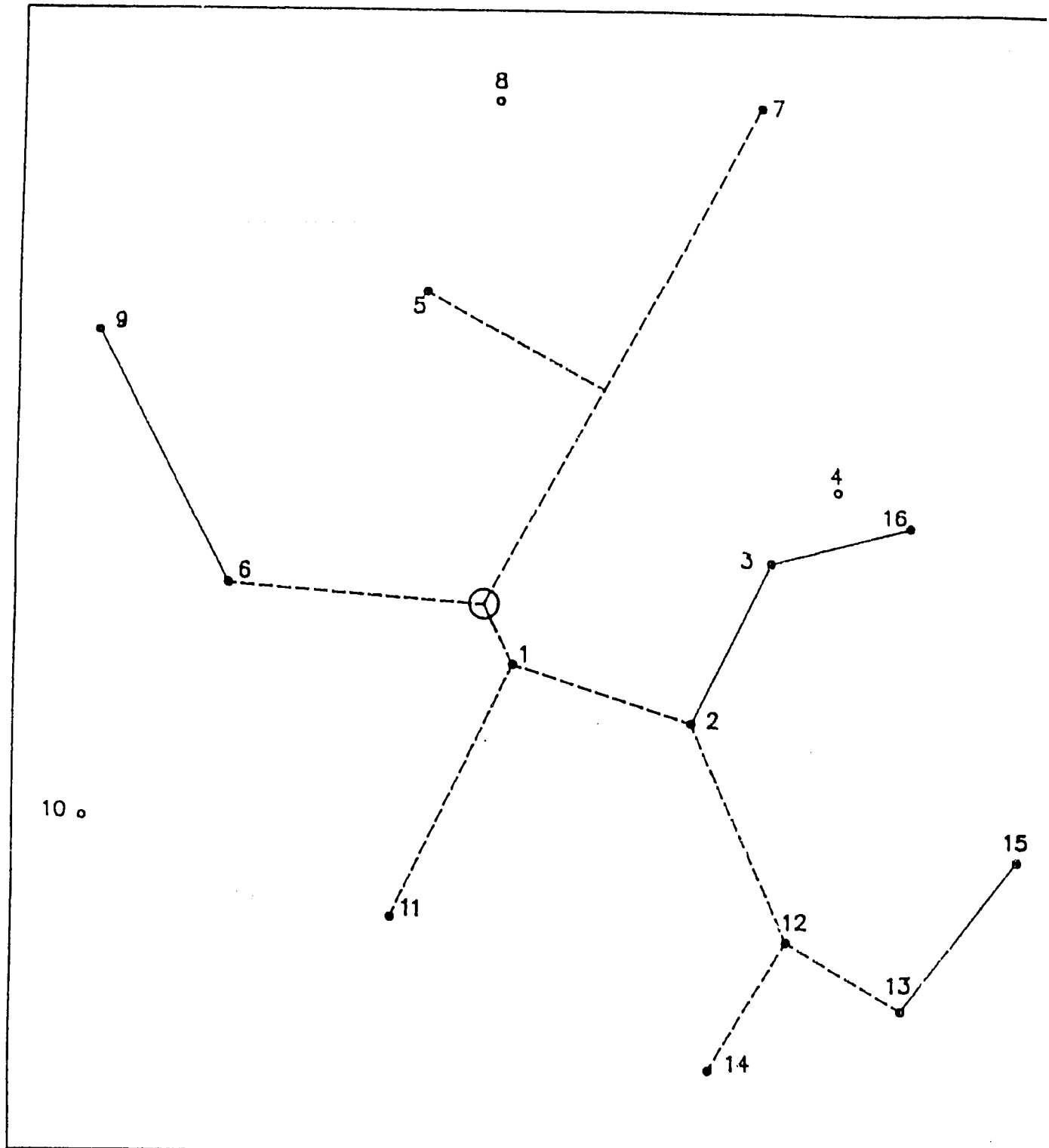

FIG. 4.4 STAGE 4 : Budget allows electrification of villages 3, 9, 15 and 16

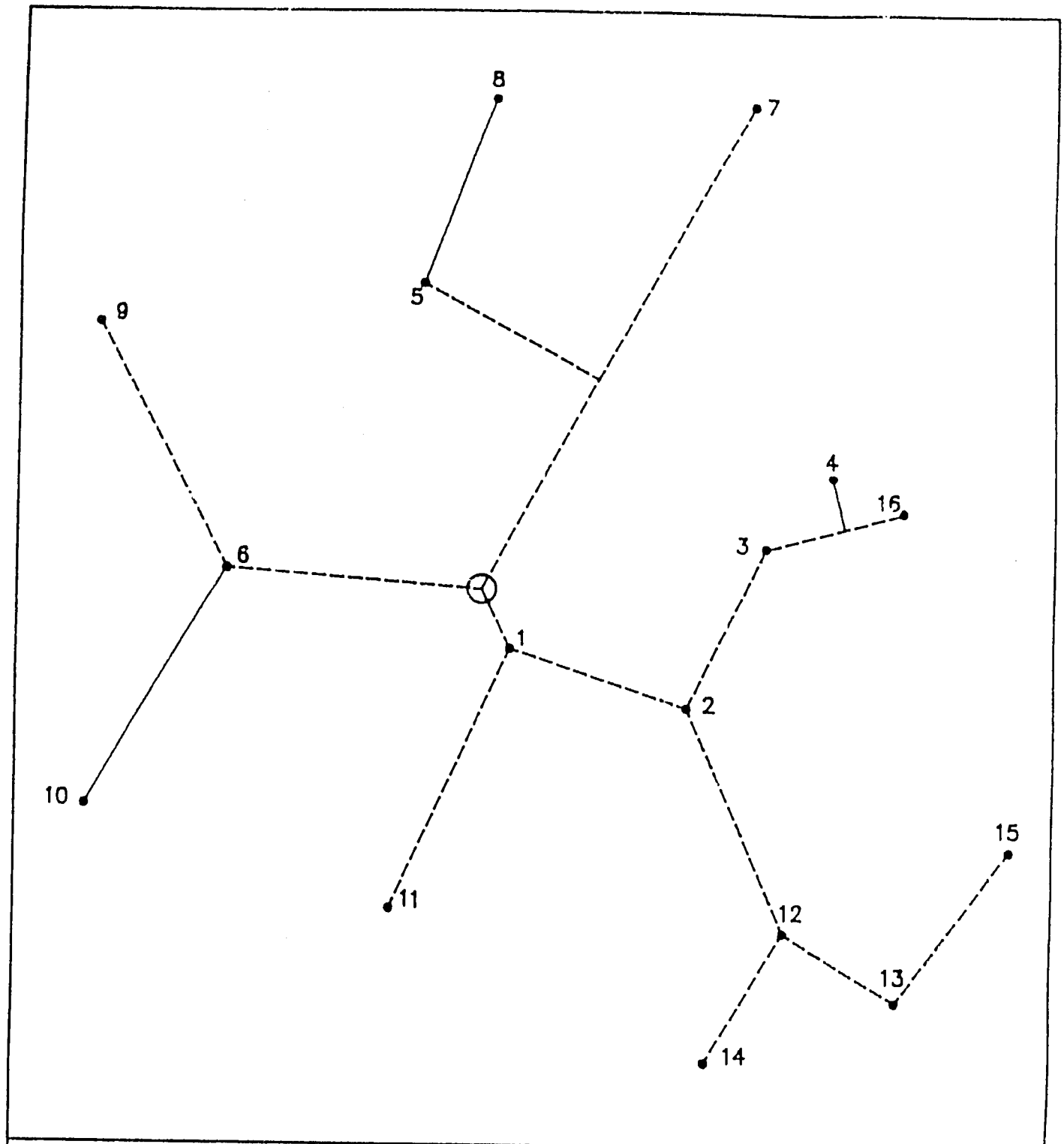

FIG. 4.5 STAGE 5 : Budget allows electrification of villages 4, 8 and 10

TABLE 4.8-1

PARAMETERS FOR CUMULATIVE BENEFIT-COST RATIO METHOD
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

DESCRIPTION	HOUSEHOLDS	COMMERCIAL	SMALL INDUSTRY
Peak kw per Customer at Distribution Transformer	0.42	0.39	16.74
KWH per Customer per year	492	500	12800
Benefits Rs/year (*)	509	472	16421
Number Per Village			
1. Chak 012/GD	394	3	47
2. Chak 011/GD	346	3	41
3. Chak 013/GD	213	2	26
4. Chak 010/GD	326	3	39
5. Joya	568	5	67
6. Mirak	572	5	68
7. Kchla	1034	9	124
8. Ottwal Gagar	197	2	24
9. Chak 027/GD	420	3	50
10. Chak 015/GD	254	2	30
11. Chak 014/GD	582	5	69
12. Chak 011/1R	380	3	45
13. Chak 012/1R	424	4	50
14. Chak 015/1R	474	4	66
15. Chak 010/1R	421	3	50
16. Chak 009/1R	365	3	43

Discount Rate: 10%

RE Costs: Same as in Table 4.7-1

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* The benefits used in this method are different from those in Table 4.7-1 and from the results in Chapter 3 because this analysis was performed before the results in Chapter 3 were finalized.

Table 4.8-2 PAKISTAN RURAL ELECTRIFICATION AREA PLANNING:
District Okara, Tehsil Okara

Initial Village Ranking by Cumulative Benefit/Cost Ratios (BCR)

Village Name	Village Number	Previous Village [1]	Cumulative BCR	Rank
CHAK 012/GD	1	0	59.3	1
CHAK 011/GD	2	1	27.8	2
CHAK 014/GD	11	1	25.5	3
CHAK 015/IR	14	12	23.8	4
CHAK 010/IR	15	13	23.6	5
CHAK 012/IR	13	12	23.4	6
CHAK 011/IR	12	2	21.7	7
MIRAK	6	0	20.0	8
CHAK 010/GD	4	3	19.8	9
CHAK 009/IR	16	3	18.3	10
CHAK 013/GD	3	2	17.0	11
KOHLA	7	17	16.8	12
CHAK 027/GD	9	6	15.3	13
CHAK 015/GD	10	6	14.4	14
JOYA	5	17	11.7	15
OTTWAL GAGAR	8	5	11.0	16
FICTIVE	17	0	0.0	17

[1] Indicates the village immediately before on the same distribution feeder or line. For example, village 12 must be electrified before village number 13.

Table 4.8-3 PAKISTAN RURAL ELECTRIFICATION AREA PLANNING:
District Okara, Tehsil Okara

Village Ranking Accounting for Location on Distribution Line

Village Name	Village Number	Previous Village	Cumulative BCR	Initial Rank
CHAK 012/GD	1	0	59.3	1
CHAK 011/GD	2	1	27.8	2
CHAK 014/GD	11	1	25.5	3
CHAK 011/IR	12	2	21.7	7
CHAK 015/IR	14	12	23.8	4
CHAK 012/IR	13	12	23.4	6
CHAK 010/IR	15	13	23.6	5
MIRAK	6	0	20.0	8
CHAK 013/GD	3	2	17.0	11
CHAK 010/GD	4	3	19.8	9
CHAK 009/IR	16	3	18.3	10
FICTIVE	17	0	0.0	17
KOHLA	7	17	16.8	12
CHAK 027/GD	9	6	15.3	13
CHAK 015/GD	10	6	14.4	14
JOYA	5	17	11.7	15
OTTWAL GAGAR	8	5	11.0	16

In Table 4.8-2 the column labeled "Previous Village" is the number of the village immediately before on the same distribution line, with "0" referring to the grid station. For example, Fictive (a junction point for computing th B/C ratio where no village is located) is served directly from the grid station, and is on the same line and immediately before Kohla. This means that Kohla can only be electrified after Fictive. Similarly, Chak 011/IR mus be electrified before Chak 012/IR and Chak 015/IR. Thus the order in which villages are electrified must be adjusted from the list indicated by the BCR ranking.

Table 4.8-3 is a revision of Table 4.8-2, whereby villages are moved up the list so that the villages are electrified in the required order. Note that the decision to electrify village number 15 implies the need to electrif villages 13, 12, 2, and 1. However, village 14 has a higher B/C ratio, and will therefore be electrified before villages 13 and 15. In the event that the cost of electrifying village 14 is higher than the costs of electrifying villages 13 and 15, and there are insufficient funds in the budget to electrify village 14, villages 13 and 15 may be electrified first.

To illustrate the differences between this B/C ratio approach and some of those used in the past, a comparison is presented in Table 4.8-4. The three methods compared are the simple population, population-distance (direct from grid), and the cumulative B/C Ratio method. The table indicates the substantial difference in the resulting ranking.

4.8.2 Case Study: Baluchistan, District Kalat, Tehsil Kalat

This case study examines three different aspects of village electrification: from new feeders, extensions of existing feeders, and decentralized generation. Figure 4B-1 shows the 20 sample villages that are or can be electrified from the grid. Also considered but not shown on the figure are six villages located from 10 to 30 km from the planned grid for which decentralized diesel generation is more economic than grid-based electricity based on a separate analysis discussed above in Section 4.7. For the purposes of this example, villages 1 through 9 are already electrified. Appendix H-2 presents some supporting data and calculations.

In this case study, the cluster method will be applied. The clusters are defined by applying the rule that each cluster covers the village(s) to be electrified using the same new feeder or the same extension (or branch) of an existing feeder for grid-based electricity. For decentralized generation (DG), each cluster consists of the village(s) electrified by one diesel plant. From the central grid there are four clusters:

- CG-1: villages 10 through 14
- CG-2: village 15
- CG-3: village 16
- CG-4: villages 17 through 20

Table 4.8-4

Comparison of Village Ranking
Based on Different Approaches

VILLAGE NUMBER	POPULATION BASED	POPULATION DISTANCE INDIVIDUAL VILLAGES(*)	CUMULATI BENEFIT-RATIOS
	(1)	(2)	(3)
1	9	1	1
2	12	4	2
3	15	12	9
4	13	13	10
5	4	2	15
6	3	3	8
7	1	5	12
8	16	16	16
9	8	11	13
10	14	15	14
11	2	6	3
12	10	7	4
13	6	8	6
14	5	9	5
15	7	10	7
16	11	14	11

(*) Distance from Grid substation to village

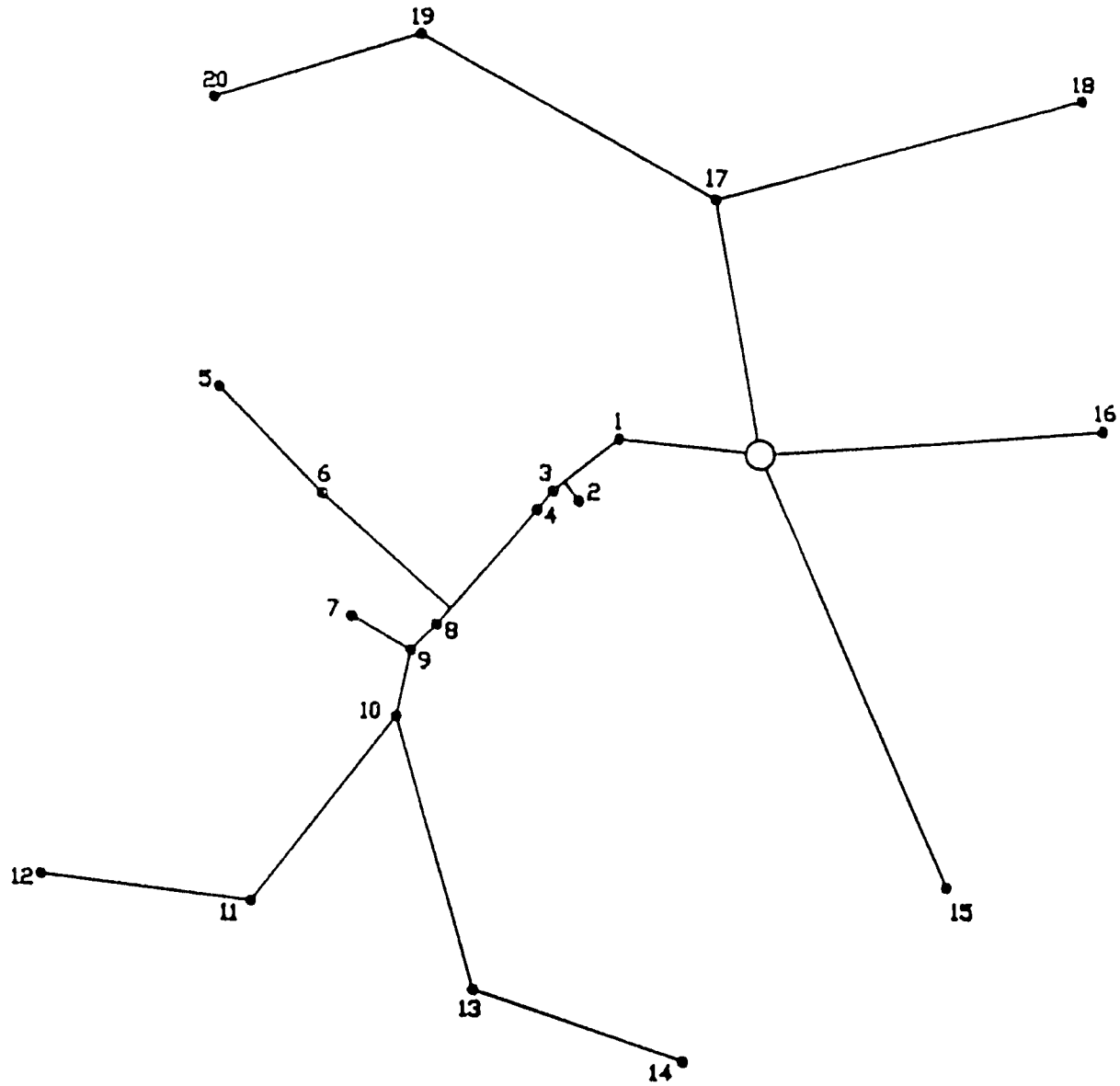

FIG. 4B-1 Sample area. Tehsil Kalat
Showing optional technical solution

Table 4B-1 presents the economic parameters used for these villages; all benefits and costs by customer type are included except for the area distribution (line costs between villages) which are village specific. Table 4B-2 presents the benefits and costs data for each village except again for the area distribution costs. Table 4B-3 presents all benefits and costs (including area distribution) by cluster.

For the decentralized generation diesel options, there are five clusters:

- DG-1: village A
- DG-2: village B
- DG-3: village C
- DG-4: village D
- DG-5: villages E and F

Table 4B-4 presents the economic parameters for each customer type; this table is similar to Table 4B-1 except the central grid costs are not included. Diesel generation costs are not included because they are village specific either due to economies of scale or local diesel based grids. Table 4B-5 presents the total benefits and costs for these remote villages. Cluster DG-5 is more economic than separate diesel plants as indicated by the higher benefit-cost ratio (BCR) for the two together of 0.31 versus BCRs of 0.26 and 0.19 individually. Appendix H-2 presents the basis for the diesel generation cost estimates.

The ranking of village clusters based on their BCRs is :

Cluster/Villages		Benefit-Cost Ratio
DG-5:	E, F	0.31
CG-1:	10,13,14,11,12	0.30
CG-4:	17,18,19,20	0.29
DG-1:	A	0.25
DG-2:	B	0.23
DG-4:	D	0.21
CG-3:	16	0.20
DG-3:	C	0.16
CG-2:	15	0.14

The electrification of villages, if selected according to this ranking, would proceed cluster by cluster. In this example, first villages E and F would be electrified by one diesel plant and connected by a HT distribution line. Then the existing feeder would be extended to electrify villages 10 through 14, and so on. The available budget for this district and the ranking of other clusters are not shown in this illustrative list would determine the actual villages electrified. (It should be remembered that this is a ranking of villages; and while village selection may be primarily based on this ranking, other factors may lead to the selection of other villages lower on the list.

TABLE 4B-1: ECONOMIC ANALYSIS OF DIESEL OPTIONS TO ELECTRIFY VILLAGES IN REMOTE AREAS
DISTRICT KALAT, TEHSIL KALAT (6 SAMPLE VILLAGES)

PARAMETERS FOR ECONOMIC ANALYSIS

Sr. No.	DESCRIPTION		HOUSEHOLDS LOW INCOME	HOUSEHOLDS AVG. INCOME	HOUSEHOLDS HIGH INCOME	COMMERCIAL + COMMUNITY	SMALL INDUSTRY	TUBEWELLS
A.	PRESENT WORTH OF BENEFITS							
	- Gross Benefits/Customer		525	787	1882	700	21760	16800
	- PWB @ DF=10%	Rs.	2556	3831	9162	3408	105937	81789
		(Rs . 000)	2.56	3.83	9.16	3.41	105.94	81.79
B.	PRESENT WORTH OF CAPITAL							
	- Peak kW per Customer at Distribution Transformer		0.22	0.47	1.31	0.39	16.74	10.85
	- Coincident Demand/Customer at Generation Level	kW	0.17	0.36	1.00	0.30	12.80	8.30
	- Captial Cost							
	a. Connection Cost	Rs.	840	840	840	840	6300	28175
	b. Village Distribution Cost @ 1750/kW	Rs.	385	823	2293	683	29295	0
	Sub - Total	Rs.	1225	1663	3133	1523	35595	28175
	- PW of Capital	(Rs.000)	1.84	2.49	4.70	2.28	53.39	42.26
C.	PRESENT WORTH OF ENERGY							
	- kWH per Customer		240	540	1800	500	12800	8300
	- Cost of Energy @ Rs. 0.61/kWh		0.00	0.00	0.00	0.00	0.00	0.00
	- PW of Energy	(Rs. 000)	0.00	0.00	0.00	0.00	0.00	0.00
D.	PRESENT WORTH OF COST (Rs. 000)		1.84	2.49	4.70	2.28	53.39	42.26

DISCOUNT FACTOR = 10% TIME PERIOD = 7 Years

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Table 4B-2: ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT KALAT, TEHSIL KALAT (20 SAMPLE VILLAGES)

TOTAL CAPITAL INVESTMENT, PRESENT WORTH OF COST AND PRESENT WORTH OF BENEFITS

21-Jul-88

Sr. No.	DESCRIPTION	HOUSE HOLDS				SMALL INDUSTRY	COMMERCIAL + COMMUNITY	TUBEWELLS	11 kV LINE	TOTAL CAPITAL COST (Rs. 000)	TOTAL PW OF COST (Rs. 000)	TOTAL PW OF BENEFITS (Rs. 000)
		LOW INCOME	AVERAGE INCOME	HIGH INCOME	TOTAL							
A.	PER USER (Rs. 000)											
	a. Capital Investment	9.49	18.69	49.70		629.39	15.78	415.76	56.00			
	b. Present Worth of Costs	10.95	21.98	60.68		707.47	18.83	466.39	84.00			
	c. Present Worth of Benefit	5.25	7.87	18.82		217.60	7.00	168.00	0.00			
B.	PER VILLAGE (No.)											
1.	Kohing	102	16	2	120	1	15			2233	2580	1022
2.	Baint	31	5	0	36	0	5			467	544	237
3.	Malgulzar	55	8	2	65	0	9			913	1069	452
4.	Malki	72	11	2	85	0	10			1146	1340	572
5.	Jalalabad	33	5	1	39	0	5			535	626	266
6.	Girani	105	16	2	123	1	15			2261	2613	1037
7.	Gurk	30	5	0	35	0	5			457	533	232
8.	Ahmadabad	37	6	0	43	0	5			542	631	276
9.	Ziarat	67	10	2	79	0	10			1080	1263	538
10.	Fateh Muhammad Zai	54	8	1	63	0	7			822	960	414
11.	Chhapper	55	8	2	65	0	9			913	1069	452
12.	Juman Zai	51	8	1	60	0	7			794	927	399
13.	Toghay	84	13	2	99	0	12			1329	1553	665
14.	Chatti	85	13	2	100	0	12			1338	1564	670
15.	Giamander	30	5	0	35	0	4			441	514	225
16.	Hassan Zalo	42	6	1	49	0	6			655	765	329
17.	Iskalko	165	25	4	194	1	23			3224	3740	1517
18.	Soro	55	8	2	65	0	8			897	1050	445
19.	Yousafi	39	6	1	46	0	6			627	733	313
20.	Tarik	48	7	2	57	0	5			765	895	380

Table 4B-3: ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT KALAT, TEHSIL KALAT (20 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES

CLUSTER No./ VILLAGE No.	OPTION	FROM	TO	HT Line km	CAPITAL COST (RS. 000) LINE	VILLAGE	TOTAL	PWC (Rs. 000) LINE	VILLAGE	TOTAL	PWB (Rs. 00 LINE	VILLAGE	TOTAL	NPWB (Rs.000)	BCR	RATIO NPWB : CAPITAL
CLUSTER 1																
10	2	9	10	2.0	112	822	934	168	960	1128	0	414	414	-714	0.367	-0.764
11	3	10	11	6.8	378	913	1291	567	1069	1636	0	452	452	-1184	0.276	-0.917
12	5	11	12	6.3	350	794	1144	525	927	1452	0	399	399	-1053	0.274	-0.921
13	2	10	13	8.3	462	1329	1791	693	1553	2246	0	665	665	-1581	0.296	-0.883
14	2	13	14	6.5	364	1338	1702	546	1564	2110	0	670	670	-1440	0.318	-0.846
CLUSTER TOTAL				29.8	1666	5136	6862	2499	6073	8572		2600	2600	-5972	0.303	-0.870
CLUSTER 2																
15	1	0	15	13.6	763	441	1204	1145	514	1659	0	225	225	-1434	0.136	-1.191
CLUSTER 3																
16	1	0	16	10.1	567	655	1222	851	765	1616	0	329	329	-1287	0.203	-1.053
CLUSTER 4																
17	1	0	17	7.5	420	3224	3644	630	3740	4370	0	1517	1517	-2853	0.347	-0.783
18	2	17	18	11.1	623	897	1520	935	1050	1985	0	445	445	-1539	0.224	-1.013
19	2	17	19	10.0	560	627	1187	840	733	1573	0	313	313	-1260	0.199	-1.062
20	3	19	20	6.4	357	765	1122	536	895	1431	0	380	380	-1051	0.265	-0.937
CLUSTER TOTAL				35.0	1960	5513	7473	2940	6418	9358	0	2655	2655	-6703	0.284	-0.897

Table 4B-4: ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT KALAT, TEHSIL KALAT (20 SAMPLE VILLAGES)

PARAMETERS FOR ECONOMIC ANALYSIS

31-Jul-88

Sr. No.	DESCRIPTION		HOUSEHOLDS LOW INCOME	HOUSEHOLDS AVG. INCOME	HOUSEHOLDS HIGH INCOME	COMMERCIAL + COMMUNITY	SMALL INDUSTRY	TUBEWELLS
A.	PRESENT WORTH OF BENEFITS							
	- Gross Benefits/Customer		525	787	1882	700	21760	16800
	- PWB @ DF=10%	Rs.	5250	7870	18820	7000	217600	168000
		(Rs . 000)	5.25	7.87	18.82	7.00	217.60	168.00
B.	PRESENT WORTH OF CAPITAL							
	- Peak kW per Customer at Distribution Transformer		0.22	0.47	1.31	0.39	16.74	10.85
	- Coincident Demand/Customer at Generation Level	kW	0.17	0.36	1.00	0.30	12.80	8.30
	- Captial Cost							
	a. Connection Cost	Rs.	840	840	840	840	6300	28175
	b. Village Distribution Cost @ 1750/kW	Rs.	385	823	2293	683	29295	-
	c. Generation & Transmission Cost @ 30000/kW	Rs.	5100	10800	30000	9000	384000	249000
	Sub - Total	Rs.	6325	12463	33133	10523	419595	277175
	- PW of Capital	(Rs.000)	9.49	18.69	49.70	15.78	629.39	415.76
C.	PRESENT WORTH OF ENERGY							
	- kWH per Customer		240	540	1800	500	12800	8300
	- Cost of Energy @ Rs. 0.61/kWh		146.40	329.40	1098.00	305.00	7808.00	5063.00
	- PW of Energy	(Rs. 000)	1.46	3.29	10.98	3.05	78.08	50.63
D.	PRESENT WORTH OF COST (Rs. 000)		10.95	21.98	60.68	18.83	707.47	466.39

TABLE 4B-5: ECONOMIC ANALYSIS OF DIESEL OPTIONS TO ELECTRIFY VILLAGES IN REMOTE AREAS
DISTRICT KALAT, TEHSIL KALAT (6 SAMPLE VILLAGES)

TOTAL CAPITAL INVESTMENT, PRESENT WORTH OF COSTS, BENEFITS AND B-C RATIOS

Sr. No.	DESCRIPTION	HOUSE HOLDS				SMALL INDUSTRY	COMMERCIAL +COMMUNITY	TUBEWELLS	11 kV LINE per KM
		LOW INCOME	AVE. INCOME	HIGH INCOME	TOTAL				
A.	PER USER (Rs. 000)								
	a. Capital Investment	1.84	2.49	4.70		53.39	2.28	42.26	56.00
	b. Present Worth of Costs	1.84	2.49	4.70		53.39	2.28	42.26	84.00
	c. Present Worth of Benefit	2.56	3.83	9.16		105.94	3.41	81.79	0.00
	d. Peak demand KW	0.22	0.47	1.31		16.74	0.39		
	e. Energy Consumpt per Year	240	540	1800		12800	500		
B.	PER VILLAGE (No.)								
1.	Riag Wash	86	13	2	101	0	12		
2.	Narmok Thakht	75	11	2	88	0	11		
3.	Giwan Koh	16	2	1	19	0	2		
4.	Lope	59	9	1	69	0	8		
5.	Choto	91	14	2	107	0	13		
6.	Tobo	48	7	1	56	0	7		
7.	Choto + Tobo	139	21	3	163	0	20		336

		TOTAL CAPITAL COST (Rs. 000)	VILLAGE DEMAND (KW)	VILLAGE DEMAND (KWH)	DIESEL CAPITAL COST (Rs. 000)	PV OF DIESEL OPERATING COST (Rs. 000)	TOTAL PV COST OF DIESEL (Rs. 000)	TOTAL PW OF COST (Rs. 000)	TOTAL PW OF BENEFITS (Rs. 000)	B-C RATIO
C.	PER VILLAGE									
1.	Riag Wash	227	32	37260	347	762	1109	1336	329	0.246
2.	Narmok Thakht	200	29	33040	348	715	1063	1263	290	0.230
3.	Giwan Koh	44	7	7720	144	228	372	416	65	0.155
4.	Lope	154	22	24820	324	598	922	1076	222	0.206
5.	Choto	241	34	39500	342	782	1124	1365	349	0.256
6.	Tobo	126	18	20600	293	520	813	939	183	0.195
7.	Choto + Tobo	368	52	60100	159	839	998	1702	532	0.313

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This ranking, which includes both central grid and decentralized generation, is obviously sensitive to the relative costs of generation (and transmission for the central grid) from each source. Although only approximate cost functions are necessary, as discussed above, more work would be useful to refine the costs used in this analysis. Furthermore, this refinement work would examine more closely what level of cost detail is needed or what costs can be ignored or simplified.

For example, in this analysis, the losses on the 4 km line between villages E and F are not included. They would increase total costs by less than 3 percent, but this issue should be examined in detail for if the distances are longer to determine its effect. Nevertheless, the parameters needed for the central grid remain the long run marginal costs either in terms of capacity and energy charges or peak and off-peak charges plus peak coincidence or diversity factors at the generation point. For the diesel decentralized generation option, the most important parameters are diesel capital and operating (or recurrent) costs as a function of scale.

4.8.3 Case Study: NWFP, District Bannu, Tehsil Lakki Marwat

This case is used to illustrate (1) the differences between the incremental and cumulative methods in the patterns of villages selected for electrification, and (2) the advantage of using any B/C method over those that rely strictly on the proximity to the grid. The data used for calculating these benefits and costs are presented in Tables 4C-1 and 4C-2.

Table 4C-1: Rankings of Selected Villages by Method

	Marginal Incremental	Total Incremental	Cluster	Cumulative
	3	3	3	3
	2	1	2	1
	1	18	9	8
	7	19	7	18
	18	17	1	19
	19	21	18	20
	17	7		17
	21			
Total Spent:	20,490	19,929	19,734	20,186
Total B/C:	2.76	2.75	2.68	2.60

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Table 4C-2: ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT BANNU, TEHSIL LAKKI MARWAT (21 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES FOR TECHNICAL OPTION

24-Jun-88

Village Number	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	CAPITAL COST (RS. 000) VILLAGE	CAPITAL COST (RS. 000) TOTAL	PWC (Rs. 000) LINE	PWC (Rs. 000) VILLAGE	PWC (Rs. 000) TOTAL	PWB (Rs. 000) LINE	PWB (Rs. 000) VILLAGE	PWB (Rs. 000) TOTAL	NPWB (Rs.000)	BCR	RATIO NPWB : CAPITAL
1	1	1a	1	1.050	59	2129	2188	88	2129	2217	0	6821	6821	4604	3.076	2.104
2	1	2a	2	0.060	3	556	559	5	556	561	0	1776	1776	1215	3.167	2.173
3	1	0	3	5.550	311	4485	4796	466	4485	4952	0	14321	14321	9369	2.892	1.953
4	1	4a	4	3.450	193	1552	1745	290	1552	1842	0	4982	4982	3141	2.705	1.800
5	1	0	5	10.050	563	603	1166	844	603	1448	0	1916	1916	468	1.323	0.401
6	1	6a	6	2.700	151	498	649	227	498	725	0	1605	1605	880	2.215	1.357
7	1	7a	7	5.100	286	2134	2419	428	2134	2562	0	6840	6840	4278	2.669	1.768
8	1	1	8	5.250	294	1089	1383	441	1089	1530	0	3485	3485	1955	2.278	1.413
9	1	2	9	6.600	370	2691	3061	554	2691	3246	0	8621	8621	5375	2.656	1.756
10	1	10a	10	1.050	59	1552	1611	88	1552	1640	0	4982	4982	3342	3.038	2.075
11	1	5	11	8.100	454	2475	2929	680	2475	3156	0	7915	7915	4759	2.508	1.625
12	1	11	12	4.800	269	801	1070	403	801	1204	0	2567	2567	1363	2.132	1.274
13	1	14	13	2.850	160	2493	2653	239	2493	2733	0	7967	7967	5235	2.916	1.973
14	1	15	14	3.750	210	1424	1634	315	1424	1739	0	4542	4542	2803	2.611	1.715
15	1	15a	15	1.200	67	2769	2837	101	2769	2870	0	8851	8851	5980	3.084	2.108
16	1	0	16	15.900	890	3550	4441	1336	3550	4886	0	11358	11358	6472	2.325	1.458
17	1	17a	17	4.800	269	2274	2542	403	2274	2677	0	7251	7251	4574	2.709	1.799
18	1	18a	18	0.300	17	2105	2122	25	2105	2131	0	6751	6751	4620	3.169	2.177
19	1	0	19	13.050	731	2417	3148	1096	2417	3513	0	7738	7738	4225	2.203	1.342
20	1	19	20	4.05	227	1437	1664	340	1437	1777	0	4584	4584	2807	2.579	1.687
21	1	17	21	3.750	210	1564	1774	315	1564	1879	0	5019	5019	3140	2.671	1.770

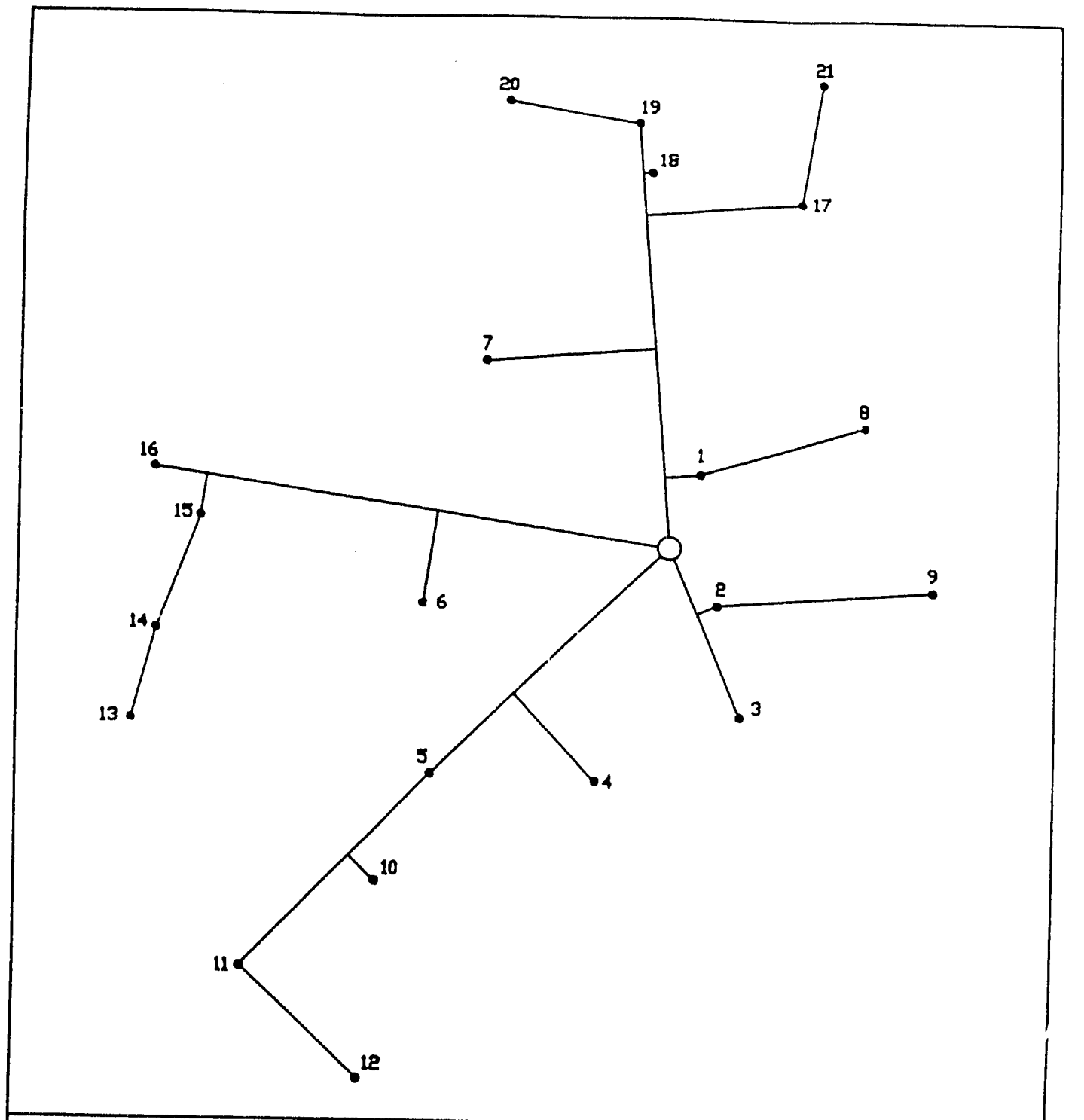

FIG. 4C-1 Sample area. Tehsil Lakki Marwat. District Bannu
Showing optional technical solution

Incremental B/C Methods

One approach to the village selection process is to make individual decisions, one village at a time, based on the best option that is available. The question here is the method of computing the benefits and costs. At one extreme, the benefits and costs for the next point are calculated and the best choice is based on the attractiveness of only the next step. This is called the "Marginal Incremental" B/C method.

Using this method, villages 1, 2, 3, 7, 17, 18, 19, 20, and 21 will be electrified if 40% of the budget necessary to electrify all of the villages is available. The main disadvantage to this method is that villages lying further along the feeder are ignored in the decision-making process. If a village with a low B/C ratio must be electrified before a village that is far more attractive, it is possible that the more attractive village will never be electrified. In this case, villages 8 and 9 are omitted, which are on the same feeders as villages 1 and 2, respectively.

To reduce this disadvantage, the logical extension of this method is to include the benefits and costs of two villages along the same feeder in the calculations of B/C ratios, increasing the number of options under consideration. This will also result in the need for iterative computations of benefits and costs, and is therefore a complex iterative process. It is not evaluated here.

Extending this process to three villages results in an even larger number of options at each step. In addition, the iterative character of the method becomes even more difficult and cumbersome.

In the other extreme case, all of the villages that lie on the rest of the feeder or branch are included in the computation of the B/C ratio. The B/C ratios are calculated based on the cumulative costs and benefits from the outside or end of the feeders inward toward the generation or substation point. This is referred to here as the "Total Incremental Method." Instead of creating an impossibly large number of possibilities, this process eliminates the need for iterative computations of B/C ratios and the number of options are equal to the number of branches available at any given time. It does, however, require repeated re-examinations of the available options and is therefore somewhat iterative.

The first decision is among the four feeders, each of which has a B/C ratio that incorporates the benefits and costs of all the villages along that feeder. The main advantage to this method that it does not require any iterative computations of B/C ratios. In addition, no village with a high B/C ratio will be ignored, even if separated from the feeder by a village with a lower B/C ratio. On the other hand, attractive villages closer in can be grouped with less attractive ones lying farther out on the feeder, resulting in a lower B/C ratio and delaying the electrification of closer, attractive villages.

In this case, the result using the Total Incremental method is very similar to that using the Marginal Incremental Method. The only difference is that villages 2 is omitted. The benefit/cost ratios are also very similar.

The Cumulative Method

The real contrast is apparent when comparing these two incremental methods to the cumulative method. The villages selected using the cumulative method are 1, 3, 8, 15, 18, 19, and 20. Besides being a very scattered pattern of villages, and therefore bypassing many villages in the process of electrification, this method results in the lowest B/C ratio of the four methods considered, only 2.68, compared to 2.75 for the Total Incremental and 2.76 for the Marginal Incremental methods.

The Proximity Method

The method that has been used in the past assigns a higher priority to those villages that are closest to the grid. These are therefore electrified first. The B/C ratio that results from this method was estimated and compared to that from the other four methods using a B/C ratio.

Using the distance-to-grid criterion alone, the villages that will be electrified (with a 40% budget limitation as above) are 1, 2, 3, 4, 5, 6, 7, 8, and 9. The total B/C ratio was only 2.40. This is obviously not the optimal combination of villages to electrify.

4.8.4 Case Study: Sind, District Thatta, Tehsil Thatta

Figure 4D-1 presents a map of the villages for this case study. The costs and benefits of electrifying the 22 villages in this area are presented in Table 4D-1. These were used in four area planning methods to rank the villages under with an available electrification budget limited to 40% of the amount required to electrify all of the villages. These rankings are listed in Table 4D-2, including the rankings using the present method, with population/distance-to-grid ratios.

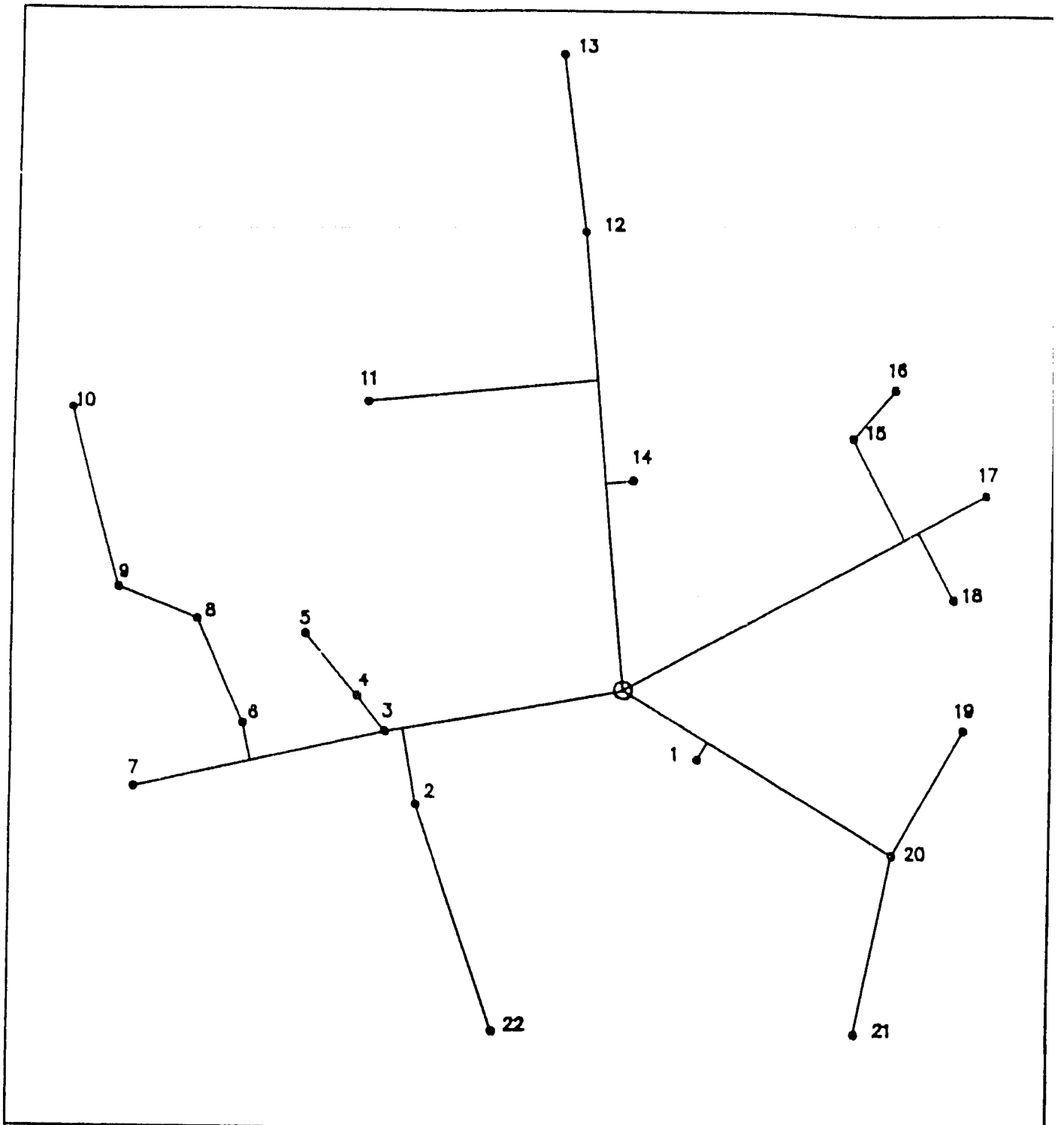

FIG. 4D-1 Sample area. Tehsil Thatta
Showing optional technical solution

Table 40 1: ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT THATTA, TEHSIL THATTA (22 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES FOR TECHNICAL OPTION

24-Jun-88

Village Number	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	VILLAGE	TOTAL	PWC (Rs. 000) LINE	VILLAGE	TOTAL	PWB (Rs. 000) LINE	VILLAGE	TOTAL	NPWB (Rs.000)	BCR	RATIO NPWB : CAPITAL
1	1	1a	1	0.250	14	697	711	21	697	718	0	2133	2133	1415	2.972	1.991
2	1	2a	2	1.750	98	2640	2738	147	2640	2787	0	8087	8087	5300	2.901	1.935
3	1	0	3	6.250	350	873	1223	525	873	1398	0	2832	2832	1434	2.026	1.173
4	1	3	4	1.000	56	1139	1195	84	1139	1223	0	3504	3504	2281	2.866	1.910
5	1	4	5	2.000	112	1326	1438	168	1326	1494	0	4059	4059	2565	2.716	1.783
6	1	6a	6	0.875	49	1331	1380	74	1331	1404	0	4076	4076	2672	2.903	1.937
7	1	3	7	6.500	364	1428	1792	546	1428	1974	0	4367	4367	2393	2.212	1.335
8	1	6	8	3.000	168	1194	1362	252	1194	1446	0	3672	3672	2226	2.539	1.634
9	1	8	9	2.250	126	833	959	189	833	1022	0	2538	2538	1516	2.483	1.580
10	1	9	10	4.750	266	911	1177	399	911	1310	0	2771	2771	1461	2.115	1.241
11	1	11a	11	6.000	336	667	1003	504	667	1171	0	2045	2045	874	1.747	0.872
12	1	0	12	11.750	658	916	1574	987	916	1903	0	2781	2781	878	1.461	0.558
13	1	12	13	4.750	266	4299	4565	399	4299	4698	0	13140	13140	8442	2.797	1.849
14	1	14a	14	0.750	42	1088	1130	63	1088	1151	0	3346	3346	2195	2.907	1.943
15	1	15a	15	3.000	168	1519	1687	252	1519	1771	0	4635	4635	2864	2.617	1.697
16	1	15	16	1.750	98	488	586	147	488	635	0	1505	1505	871	2.372	1.487
17	1	0	17	10.750	602	521	1123	903	521	1424	0	1609	1609	184	1.129	0.164
18	1	18a	18	2.000	112	1700	1812	168	1700	1868	0	5175	5175	3307	2.770	1.825
19	1	20	19	3.750	210	1335	1545	315	1335	1650	0	4090	4090	2440	2.479	1.579
20	1	0	20	8.25	462	1182	1644	693	1182	1875	0	3633	3633	1757	1.937	1.069
21	1	20	21	4.500	252	1856	2108	378	1856	2234	0	5693	5693	3459	2.548	1.641
22	1	2	22	6.250	350	971	1321	525	971	1496	0	2946	2946	1450	1.970	1.098

Table 4D-2: Rankings of Selected Villages by Method

	Marginal Incremental	Total Incremental	Cluster	Cumulative
	2	2	2	2
	3	3	3	22
	4	4	4	3
	5	5	5	4
	6	12	22	5
	7	13	6	12
	8		7	13
	9		8	
	10		9	
			10	
Total Spent:	14,038	1[illegible],356	14,224	14,852
Total B/C:	2.558	2.576	2.501	2.515

The largest benefit/cost ratio is only 3% higher than the lowest ratio. With such a small spread, this parameter is not critical to the choice of method. The choice will instead depend upon the desirability of the pattern of villages selected.

Incremental B/C Methods

Applying the "Marginal Incremental Method," which evaluates one village at a time, the first choice would be among villages 2, 3, 14, 11, 12, 15, 17, 18, 1, or 20. The first choice was to build the line to village 2. The next choices were then 3, 14, 11, 12, 15, 17, 18, 1, 20, or 22.

Examining the benefits and costs of two villages along the same feeder in the calculations of B/C ratios increases the number of options under consideration:

Option 1: Villages 2 and 22
Option 2: Villages 2 and 3
Option 3: Villages 3 and 4
Option 4: Villages 3 and 6
Option 5: Villages 3 and 7
Option 6: Villages 14 and 11
Option 7: Villages 14 and 12
Option 8: Villages 11 and 12
Option 9: Villages 12 and 13
Option 10: Villages 15 and 16
Option 11: Villages 15 and 17
Option 12: Villages 15 and 18
Option 13: Villages 17 and 18
Option 14: Villages 1 and 20

Each one of these options will generate its own B/C ratio. After the best choice is selected, another decision must be made: to build the line to both of these villages or just to the first one. In either case, all of the benefits and costs must be recalculated after each choice is made, and a new set of options generated. This is therefore a complex and highly iterative process.

Using the Total Incremental method, the first decision is among the four feeders. Each of these has a B/C ratio that incorporates the benefits and costs of all the villages along that feeder. After the decision is made to electrify village 2, there are five B/C ratios to compare: for the three remaining feeders from the grid station, the line to village 22, and all of the villages fed by the line from point 2A to village 3. At each point, the benefits and costs of all the remaining villages are included in the decision process.

The main disadvantage to this method is that it requires continual re-examination of the options available to determine the best choice.

Cluster Method

This area includes a total of six clusters. They are defined as all of the villages on the same or nearby feeders:

		B/C
Cluster 1:	Villages 2 through 5 and 22;	2.55
Cluster 2:	Villages 6 through 10;	2.44
Cluster 3:	Villages 1 and 19 through 21;	2.40
Cluster 4:	Villages 11 through 14;	2.39
Cluster 5:	Villages 15 through 18; and	2.27
Cluster 6:	A combination of Clusters 1 and 2.	2.50

Three of the four feeders are considered individual clusters, and the largest feeder was broken up into two approximately equal clusters. An alternative would be to treat this large feeder as one cluster. The decision as to whether to create smaller clusters is partially dependent on whether the rural electrification budget for this cluster is restricted by a small total district budget, or by the political desire to disperse the district budget over a larger number of clusters.

The first step in village selection using the Cluster method is to rank the clusters in terms of their B/C ratios. On the basis of the above data, the rank order of the clusters would be 1, 6, 2, 3, 4, and 5. But since cluster 6 includes clusters 1 and 2, and since the electrification of clusters 1 and 2 exhausts the budget limitation, there is in this case an unambiguous choice of villages.

Had the B/C ratio for cluster 1 been much lower than cluster 2, then the electrification of cluster 2 would have depended on the comparative ranking of cluster 6. In that case, the electrification of cluster 6 (including both clusters 1 and 2) would have depended the availability of funds for all of these villages.

The primary benefit of this method is its simplicity; the benefits and costs are straightforward and easy to compute, and it does not involve an iterative process in terms of recalculating the B/C ratios. It also minimizes the proliferation of options as electrification proceeds, as do the incremental B/C methods.

A substantial benefit of this method is that no village that is very near an existing feeder will be left unelectrified even if it has a very low B/C ratio. Another benefit is the optimization of the use of equipment and labor. Once a feeder is selected, the entire feeder is completed and all of the construction is concentrated in that location resulting in minimal movement of machinery and laborers.

An attribute of the Cluster method is that it results in the electrification of geographic groups of villages and can easily ignore villages located elsewhere that have very attractive individual B/C ratios. The extreme, as demonstrated in this case, is that all of the selected villages are located in one part of the area, and all other villages and clusters remain unelectrified.

Cumulative Method

This method is the reverse of the "Total Incremental" method, in that B/C ratios are computed for all villages starting from the grid station and working outward. The B/C ratio of any village at the end of a feeder incorporates the costs and benefits of all the villages between it and the grid. Using this method, the villages selected were similar to those using the Total Incremental method, except that village 22 was included.

This process involves the selection first of the village with the highest B/C ratio in the area. If the electrification of this village requires the electrification of others that are nearer the grid, then these must be electrified first even if their B/C ratios are lower than other options.

This is amply illustrated by this particular area plan. After the electrification of villages 2, the second ranked village is 5. But in order to electrify village 5, villages 3 and 4 must be electrified first, even though they are ranked 15th and 3rd, respectively. In order to electrify village 13, which is ranked 4th, village 12, which is ranked 20th must be electrified first.

The advantage of this method is that, as with the cluster method, little iteration is needed as the village ranking process continues: no recalculation of B/C ratios and no re-examination of options. This advantage also leads to disadvantages in that villages near branches that are already ranked might be overlooked.

This problem arises because projected distribution costs to unelectrified villages are not recalculated (that is, reduced) after part of their feeders are constructed, in order to electrify other villages. This disadvantage could be reduced by recalculating the distribution costs after one or more villages are electrified. This recalculation could be carried out after each village is electrified, or after a full year's budget has been expended. In either case, the advantage of ease of implementation is reduced.

Variations of this method could be developed to compromise between its advantages and disadvantages. For example, all "T-Offs" or branches with only one village can be included among the costs and benefits of the main trunk. In the case presented here, village 14 would not be considered as a separate branch.

4.9 Concluding Remarks

The important changes/revisions to policy that are discussed in this chapter include:

1. Implementation of initial National RE budget allocations to the Provinces and allocation of the Provinces' RE budgets to its districts in accordance with the revised procedures which weigh population and development potential.

2. Investments in villages/settlements (or clusters of villages/settlements) should be selected starting from the highest economic Benefit/Cost ratio (even if less than 1) and proceeding in the order of decreasing B/C until the area budget is exhausted.

4.9.1 Village Selection Methods

This chapter has presented four methods for selecting villages for electrification that incorporate Benefit/Cost ratios. The major advantages and disadvantages to each of the methods discussed above relate mostly to the patterns in which villages are electrified. While there are some differences in the benefit/cost ratios that each method implies, these differences are relatively small.

The main disadvantage to the Marginal Incremental method is that it tends to ignore the benefits of villages lying further along the feeder. To compensate for this, it is possible to extend the B/C computation to include more villages along the feeder. But if this extension does not go so far as to include all of the villages lying further out on the feeder or branch, the process becomes increasingly cumbersome.

Once the Marginal Incremental method is extended to include all of the villages as part of the benefit and cost calculations, it is no longer an iterative recalculation process and the benefits and costs of all potential villages are included in the ranking process. However, this method, which is called the Total Incremental method, requires a continual re-examination of the options.

The disadvantage of the Cluster method is that it may result in the omission of villages with high B/C ratios if these villages are in a cluster with low B/C ratios. This can also work in reverse, by including villages with low B/C ratios because they are in a cluster with a high B/C ratio.

The primary advantage of this method is that is its simplicity of application. In that sense, it also overcomes many of the shortcomings of other methods. It will also include villages very near an existing feeder in the B/C analysis even if they have very low B/C ratios.

The Cumulative method is more complex than the Cluster method, and tends to bypass villages that are very close to the existing grid.

While there is no one method that is clearly superior to the others in all respects in this example, the Cluster method, due to its simplicity, seems to be the best option among the four.

In the follow-on planning work, the ranking method will be refined and, if useful, computerized. Refinement of the method will be partially based on discussions with field personnel who will be using it.

Although the data in this study can be used now, refinement of basic parameters for financial and economic evaluation will be required for the development of a data base of all settlements and villages. This data base needs to be developed to facilitate the selection of villages and tubewells on the basis of economic criteria. These data issues are discussed further in Chapter 6.

To ensure that this procedure can go forward, guideline documents must be prepared covering detailed procedures for village selection criteria, and parameters for financial and economic analysis.

Once this standard method has been agreed upon, the planning, technical design, costing, financial and economic evaluation of numerous villages (including tubewells etc.) proposed for electrification can be developed. This will ensure that the total number of compiled rural electrification investment project proposals that are deemed feasible and are on hand is larger than the number for which funding is available. The selection of projects for execution in any year will then be based on this total list of projects. Annual economic evaluations can also include special political or social considerations.

Once the villages have been selected, it is necessary to examine the financial implication for the utility. Based on the tariffs and the financial costs of RE, the revenues and costs for the selected area of electrification can be estimated. Based on this work, financial decisions concerning tariffs and transfer payments to WAPDA either for capital or recurrent costs can be made.

To address the social and political issues for the electrification of villages not selected, it is possible to set up a special fund. This fund could be used to electrify villages with B/C ratios below a specific or minimal level. This B/C level would be based on the lowest levels for villages electrified by the selection approach described in this chapter. The electrification of villages with low B/C ratios by a special fund would make explicit the costs of meeting various political and social objectives. This minimum B/C ratio could be used to serve as a cutoff for funding from standard RE funds.

Chapter 5

Technical Issues and Choices

A More Cost-Effective Approach to Rural Electrification

WAPDA's existing rural electrification program is based on technical standards and specifications developed twenty years ago for both urban and rural electrification. The current method of distribution network expansion and construction in rural areas results in high cost of construction for villages and tubewells for irrigation. WAPDA's rural electrification costs are some of the highest among the Asian countries.

Against this background, the examination of different technical aspects of rural electrification carried out in this study indicate that rural electrification costs can be greatly reduced by an approach tailored to rural conditions. A detailed examination of different areas where potential cost savings exist is made in section 5.2. The remaining part of this section summarize the findings.

5.1.1 Possible Areas for Improvement

Distribution in rural areas needs the following improvements in planning, design and construction:

- More use of higher primary voltage
- Broader mix of phase options
- Wide use of prestressed concrete structures for both HT and LT lines
- More use of smaller conductors below 25 mm^2 for individual loads
- Less use of LT lines
- Better matching between transformer capacity and demand.
- Possibly less stringent requirements on transformer losses
- More use of capacitors
- More use of voltage regulators
- More detailed planning, design and engineering
- More cost optimization for equipment and materials selection

5.1.2 Recommendations for Rural Electrification Planning, Design and Construction

Based on detailed examination of different options, it is recommended that a new cost effective approach to rural electrification expansion should be adopted by WAPDA, without any delay. The elements of this approach are as follows:

1. Organization

Establish a separate and strong rural electrification Office with responsibility for rural electrification planning, design and engineering at the headquarters and AEB level as outlined in Chapter 2.

2. Standards, Specifications and Guidelines

Develop a comprehensive set of standards, specifications and guidelines for low cost rural distribution system expansion and rehabilitation, including guidelines for related transmission and grid station expansion. These standards and guidelines should be included in a new "Technical Manual for Low Cost Rural Electrification Expansion and Rehabilitation in Pakistan".

3. Poles

As soon as possible, abandon use of steel lattice structures for network expansion and rehabilitation in rural areas. Use only low cost prestressed concrete poles.

Set a target for the design, prototype development and testing of low cost poles to substantially reduce line costs.

Examine WAPDA's existing prestressed concrete pole plants, develop and implement a plan for a three shift operation to increase capacity of production.

Encourage the private sector to establish new pole plants for prestressed concrete poles. The existing steel lattice pole suppliers should be encouraged to convert their plants to new requirements.

Stop the use of 36 ft. prestressed pole for HT lines. Use this pole only for composite lines, if any.

4. Conductors

Introduce low cost conductors such as steel cored aluminum conductors of size 10 mm^2 for some individual loads (such as tubewells).

Select conductors only on the basis of economic net present worth of capital, O & M and energy loss costs.

Before making decisions on conductor selection, introduce economically feasible maximum capacitor application and voltage regulation.

Before changing conductors consider all other options (bifurcations, express feeders, voltage regulation, upgrading of voltage etc.) and determine the most economical option.

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5. Transformers

Review transformer design and consider introduction of:
- o Transformer sizes more tailored to actual demand levels
- o Low cost single phase transformers

Introduce both 11kV/0.42kV/0.23kV and 33kV/0.42kV/0.23kV single and 3-phase transformers of sizes 5, 10, 15, 20, 25 and 50 kVA. Introduce low cost 3-phase transformers of sizes 100 - 630 kVA.

Introduce low cost fixed tap voltage booster transformers.

Eliminate items in transformer design which are not needed (fuses on HT, bird protection tap changer, cooling for 40 deg C and 50 deg C temperature rise in oil and winding). Introduce LT fuse on transformers to eliminate excessive rate of burn out.

Introduce more cost effective transformer designs through study tours in other utilities abroad.

Initiate detailed design studies of transformers.

6. Generation, Transmission and Grid Stations

Examine the attractiveness of decentralized generation options under all projects and coordinate planning and extension of transmission and grid station facilities with rural electrification expansion.

Evaluate all new transmission line and grid station expansions to include distribution expansion options (33 kV vs. 11 kV) to ensure that the large potential savings in distribution are not lost.

Initiate detailed design studies of integrated transmission, grid station and distribution expansion in selected areas.

Develop a technical instruction manual for integrated transmission and distribution network expansion for rural areas.

7. Primary Voltage and Phase Options

In all new areas, introduce 3-phase, 33 kV distribution on main feeders and 1-phase 33 kV, phase to phase distribution on all branch lines.

Examine conversion of 11/0.4 kV systems to 33/0.4 kV in existing areas. Use the salvaged equipment in other areas for replacements. Where 33 kV is not a viable option, introduce 11 kV three phase on main lines and 11kV, phase to phase, single phase lines on branch circuits.

Convert all existing LT lines for tubewells and other loads to single phase HT

Initiate detailed engineering studies of primary voltage and phase options in selected areas under rural electrification.

8. Low Voltage Distribution

Reduce LT distribution to the absolute minimum. Carry out detailed studies to examine viability on the basis of existing and projected loads.

Introduce insulated twisted conductors with related hardware for village distribution.

Introduce multiple service cables.

Initiate detailed engineering studies for LT distribution design in a selected number of villages to incorporate the above ideas. Evaluate the conventional and new approach thoroughly.

9. Auto-Reclosers and Sectionalizers

Initiate studies and data collection to evaluate the need for auto-reclosers and Sectionalizers and their costs and benefits.

10. Meters

Introduce new meter standards, surveillance and calibration practices as well as time of use and kVARH meters. To reduce energy pilferage in Rural Electrification, meter installation standards must be reviewed. The design, construction and installation standards should be revised to make meters tamper proof. Sealing of meters in the factories, sealing of anti-theft boxes using resins, introduction of breakable meter covers in case of tampering, and other methods should be tested. Independent meter inspection by companies of repute may be introduced to detect meter tampering. Exemplary disciplinary action should be taken in case of WAPDA staff in whose areas malpractices are found.

11. Capacitors

Initiate detailed studies on capacitor applications to determine the need of capacitors in rural distribucion, grid stations and transmission.

Make capacitors mandatory for all induction loads.

Install capacitors on all existing motors.

Initiate a study to introduce factory installed capacitors on all new motors and fluorescent lamps for rural electrification.

Evaluate existing grid station capacitor installations.

Initiate a study to examine the potential of local manufacturing for all types of capacitors.

12. Voltage Regulation

Initiate a study of voltage regulation at grid stations, feeders and customer installations and their economic relationship.

Install voltage regulation at all grid stations.

13. Other Technical Issues

Introduce lower cost connectors for LT service connections.

Introduce load management on all motor loads.

Introduce a more effective material management program.

Identify use of current limiters for tariff development.

Study the economics of using shorter time periods for the selection of transformer capacities and LT and HT lines.

Introduce less expensive stays and earthing.

Introduce load management time switches for motor loads only.

Introduce single phase motors up to 3 HP without phase converters and larger three phase motors with phase converters in the case of new single phase HT distribution.

5.1.3 Possible Cost Savings with the New Rural Electrification Standards in New Areas

A detailed examination of different cost saving options is made in section 5.2. The basic concepts were applied to the electrification of a sample area in Punjab (Table 5.1). It was found that the capital cost savings in transmission, grid stations and rural distribution expansion can be about as 38% as compared to the existing 132/11 kV grid system and 11kV distribution lines using steel lattice poles. The total cost of RE over 30 years including capital, O&M, and energy losses can possibly be reduced by about 33%.

Savings in Capital Costs

o Transmission & grid stations	55%
o Rural Distribution Expansion	30%
Weighted Average of Total Savings for RE:	38%

Present Value of Total RE Cost Savings (Over 30 Years)

o Capital and O&M	38%
o Energy Losses	15%
Present Value of Total Costs:	33%

5.1.4 Possible Cost Savings with New Standards in Existing Areas

Considerable cost savings are possible in expansion of distribution networks in existing electrified areas through adoption of new technical standards. Major areas where different options should be examined are as follows:

- Economic evaluation of conversion or expansion of existing 132/11 or 66/11 kV grid stations to 132/33 or 66/33 kV.

- Economic evaluation of conversion of 11 kV feeders to 33 kV through installation of 11/33 kV step-up transformers, replacement of 11/0.4 kV transformers by 33/0.4 kV transformers and replacement of 11 kV insulators.

- Evaluation of all other options such as cheaper poles, economic conductors, single phase options, conversion of LT lines to HT, matching of transformer capacity with demand, installation of insulated conductors, capacitors and voltage regulation.

In existing electrified areas, rehabilitation measures should include conversion to higher primary voltage and transfer of load to adjoining 33 kV or 11 kV feeders. All the technical options applicable to new areas can be considered in existing areas and should be evaluated taking into account the costs and benefits of conversion to new standards.

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TABLE 5.1

COST SAVINGS DUE TO NEW APPROACH IN RURAL ELECTRIFICATION IN A SAMPLE AREA IN PAKISTAN

DESCRIPTION	PRACTICE: Existing	PRACTICE: Low Cost	COST Rs. (000): Existing practice	COST Rs. (000): New approach	COST SAVING: Rs.(000)	COST SAVING: %
A. CAPITAL COSTS						
1. Transmission & Grid Stations						
a. Transmission	132 kV	132 kV	94,500	24,525		
b. Grid Stations	132/11 kV	132/33 kV	60,000	40,000		
			154,500	64,525	84,975	55
33 kV Line						
a. Three Phase	Not applicable	33 kV, 3-Phase & 1-Phase LCP -PSC	0	15,679		
b. Single Phase	Not applicable	Wider range of Conductors	0	47,077		
			0	62,756		
3. 11 kV Line						
a. Three Phase	11 kV, 3-Phase Steel lattice	Not applicable	160,775	0		
b. Single Phase	Standard Conductors		0	0		
			160,775	0		
Total HT Lines			160,775	62,756	98,019	61
4. Distribution Transformers						
a. Three Phase	3-Phase 11/0.415 kV	1-Phase, 33/0.415/0.23 kV Upto 25 kVA, 3-Phase, 33/0.415 kV for 50-200 kVA	83,212	48,650		
b. Single Phase			0	45,890		
			83,212	94,520	(11,308)	-14
5. LT Line						
a. Three Phase (52 km)	3-Phase & 1-Phase Steel Lattice	3-Phase & 1-Phase LCP - PSC	6,124	3,402		
b. Single Phase (468 km)			40,957	30,622		
			47,081	34,024	13,057	28
6. Service Connections						
a. Three Phase (1500)	Seperate service cable	Multiple Service cable	5,850	5,250		
b. Single Phase (20000)			24,000	20,000		
			29,850	25,250	4,600	15
7. Voltage Regulators	11 kV	33 kV	455	3,118	(2,663)	-585
8. Capacitors						
a. Switched	11 kV	33 kV	1,495	1,794		
b. Unswitched			1,869	2,243		
			3,364	4,037	(673)	-20
9. Phase Convertors (1500 @ 3000 Rs.)	Not Applicable	Tubewell loads	0	4,500	(4,500)	
10. Total of Transmission & Grid Stations			154,500	64,525	84,975	55
11. Total of Distribution			324,737	228,205	96,532	30
GRAND TOTAL OF CAPITAL COSTS			479,237	292,730	181,507	38
B. TOTAL PRESENT VALUES						
1. Capital Plus O & M Costs			637,385	395,881	241,404	38
2. Energy Losses						

5.2 Analysis of Technical Options

The cost, quality of supply and reliability of a rural distribution system is dependent upon the different technical options available for electrification of a village, a group of villages, an area or a group of areas. The technical options in a new or already electrified area cover some fundamental issues such as (1) the choice between extension of electricity grid or decentralized generation, (2) choice of voltage and routes for transmission lines, (3) choice of primary voltage for power distribution, (4) locations and sizes of grid sub-stations, (5) choice between three phase and single phase network, (6) equipment selection such as transformers of different sizes and characteristics and (7) service reliability and voltage regulation standards.

The standards, specifications and guidelines for distribution planning and design govern the final configuration, sizing and quality of the distribution system.

Even if the standards, specifications and guidelines were suitable from the engineering acceptability viewpoint, the application of these standards can result in low cost or high cost solutions depending upon whether the optimized solution was developed or whether the cost optimization aspects were totally ignored.

Under the current study, the technical issues and options have been examined through a number of case studies which illustrate the applicability of the basic concepts in sample areas in Punjab, Sind, NWFP and Baluchistan.

Rural electrification Planning also covers an important aspect of the service to the customers - namely service quality and reliability. Both service reliability and service quality have cost implications.

The question of investments in rural expansion versus intensification should also be examined with reference to the available technical options, costs and benefits.

The choice of transmission line voltage is made by WAPDA on the basis of demand forecasting by grid stations and load flow studies for design of the transmission network. These studies are, however, not adequately integrated with the optimized choice of primary distribution voltage and the number of grid sub-stations. The configuration of the transmission network for a 132/11 kV system will be quite different from a 132/33 kV system. Consequently, the optimization studies for transmission line planning should look at the total system investment, operating costs and energy losses and compare different demand levels and development patterns.

In the current WAPDA system, the 66 kV and 132 kV transmission system planning and design is not a responsibility of the distribution organization as the definition of distribution restricts distribution to the 11 kV bus-bars of the grid substations. The transmission line planning is done by the transmission & grid planning department and there is a lack of co-ordination among the optimization of the transmission lines, the rural distribution system expansion, and rehabilitation.

Case Studies for Cost Optimization and Technical Options

To examine the viability of different technical options and solutions, a number of design and case studies were carried out. The primary objective of these case studies was to illustrate the applicability of some of the basic design and planning concepts discussed earlier in this chapter. Each of these case studies is briefly discussed in the following sections. The sample areas which form the basis of the data in the case studies relating to technical supply options were as follows:

- Punjab : Tensil Okara, District Okara
- Sind : Tehsil Thatta, District Thatta
- NWFP : Tehsil Lakki Marwat, District Bannu
- Baluchistan : Tehsil Kalat, District Kalat

In the cost analysis, the total costs are the sum of capital costs and the present value or worth of (i.) operating and maintenance and (ii.) energy losses. A 30 year time period is used as the life of equipment. Annual operating and maintenance costs for all equipment were estimated as 5 percent of total capital costs. In future work, this percentage should be more precisely estimated by type of equipment. Energy losses are valued at 2 Rs./kwh. This high cost is still substantially less than that estimated in Table 3.4-5 above. This cost is partially due to the very low load factors exhibited by rural demands. Furthermore, expected continuation by rural demands. Furthermore, expected continuation of loadshedding and generation shortfalls argue for a high value for electricity. The analysis does not include salvage values because its present value after 30 years is not very large.

The cost evaluation methodologies used in this plan are based on various simplification which need to be reviewed in future work. For example, most calculations for network design were performed on the basis of 10th year demands being present for the entire 30 year time period. A more detailed approach would require demand forecasts and network and cost analysis for each year. Future work for project design should utilize more vigorous analysis.

Equipment costs include materials, labor, overheads and transportation. All costs except materials are estimated to be equal to 25 percent of the total materials cost.

5.2.1 Equipment, Material and Construction

Once the electric distribution equipment and materials have been standardized and specified the selection of suitable sizes and types of equipment and material for a particular application can result in optimization of costs. Major items of material and equipment where considerable savings can be made are (1) poles (2) conductors, (3) transformers and (4) service cables. Choices of suitably reliable metering is important from the revenue collection and demand management viewpoints. Use of auto-reclosers and Sectionalizers can improve system reliability. Capacitors and voltage regulators contribute towards improvement of service quality and reliability.

Standards, Specifications and Guidelines

Currently, the same distribution standards, specifications and guidelines are being used by WAPDA in both urban and rural areas. In view of the need for cost optimization, the standards for rural electrification systems must be revised. Some of the key areas to be looked into are the planning and design criteria, equipment and material specifications, and standards and guidelines.

5.2.1.1 Poles

A detailed design study of different pole options has been carried out under the current project. It has been concluded that the design of existing distribution poles needs to be changed radically to reduce pole costs.

Among the existing pole options, the 31 ft. prestressed PC pole offers the best solution and can be used for both HT and LT lines to maintain the desired clearances. Considerable cost savings can be achieved by using this solution.

Distribution Pole Design

The recommended pole spans for different types of poles are based on the lesser span either due to the pole strength or sag-tension considerations. The spans by pole strength are based on the wind pressure, height of pole, windward surface, form factor, vertical or horizontal formation of conductors, the conductor diameter and factor of safety. The two key design parameters in the WAPDA case are wind pressure (8 lb./sq. ft.) and factor of safety (2.5). Higher wind pressure and/or factor of safety will restrict the design, and the pole spans will be reduced. An examination of both of these parameters can result in a better choice of values which may lead to cost reductions due to longer span lengths.

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Lower parameter values in some circumstances can imply the need for higher conductors although this may cause damage to some lines. This may be negligible in comparison to the overall cost savings. Factors of safety less than 2.0 are being used in other countries. A closer examination of these issues should be made.

The span lengths by sag-tension calculation are also based on factors of safety at the design temperatures, the weight and breaking strength of the conductors, wind pressure, ice loading, modulus of elasticity and coefficient of expansion of the conductor. Detailed review of these design calculations will reveal that the allowable span length by sag-tension can be influenced by the choice of basic parameters.

Detailed design options of different poles were studied and 14 different poles (2 wood, 3 steel lattice and 9 prestressed concrete) were studied to determine the recommended span lengths by pole strength and sag-tension calculations. This study shows that the choice of cheaper poles can reduce the costs of distribution lines considerably:

Economic design of poles

At present, WAPDA is using the following four types of poles:

- Steel lattice

  34.66 ft., 213 kg pole for HT
  31.17 ft., 136 kg pole for LT

- Prestressed concrete

  36.00 ft., 1079 kg pole for HT
  31.17 ft., 696 kg pole for LT

Under the WAPDA/USAID Project two types of poles were studied.

- Steel lattice

  31.17 ft., 150 kg HT & LT pole

- Prestressed concrete

  31.17 ft., 700 kg HT & LT pole

The light 31.17 ft. 150 kg steel lattice pole was designed, tested and found successful.

In the present analysis, eight different types of additional poles were studied.

- Wooden poles

  36 ft., 203 kg HT pole
  30 ft., 151 kg LT pole

- Prestressed concrete

  29.6 ft., 391 kg HT & LT pole
  29.6 ft., 470 kg HT & LT pole
  26.2 ft., 317 kg HT & LT pole
  26.2 ft., 364 kg HT & LT pole
  24.6 ft., 265 kg HT & LT pole
  24.6 ft., 310 kg HT & LT pole

The six light weight prestressed concrete poles included in the analysis are currently being used in India. These poles weigh less than half the current prestressed poles being used by WAPDA.

The primary objective of the study was to determine feasible span lengths for different conductor types both from sag-tension and pole strength considerations. Once the spans were calculated, cost comparisons were made to evaluate the most economical pole type for different conductor types.

Detailed analyses of all the cases are given in a separate volume entitled "Detailed Design Studies of Distribution Pole Options". The results of the study are summarized in "Annex T1 : Design Studies of Pole Options". The major conclusions from this study are summarized here.

Spans for three phase HT lines

Recommended spans for existing WAPDA structures vary between 570 and 722 ft. for steel lattice and between 656 and 754 ft. for prestressed concrete structures and conductors ranging from Dog to Mole. The span length currently being used by WAPDA is 440 ft. The low cost structures have span lengths ranging from 221 to 551 ft. depending upon the structure and conductor type.

Spans for LT lines

Recommended spans for steel lattice pole and conductors Gnat - Wasp vary between 251 and 328 ft. and for prestressed concrete pole the span is 459 ft. The current span length specified by WAPDA is 220 ft. The use of horizontal formation increases the pole spans considerably. The low cost structures have span lengths ranging between 52 and 295 ft. for vertical formations.

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Cost Comparisons and Conclusions

Cost comparisons for items that vary with the type of pole were made for all conductor types and at wind pressures of 8 lbs. and 10.22 lbs. per sq. ft. In all cases, the low cost prestressed poles were least expensive for HT, LT and composite lines.

Comparison of Low Cost Poles with Standard WAPDA Poles

The cost of distribution lines can be drastically reduced by the introduction of low cost poles. Tables 5.2 - 5.4 summarize cost per km of HT, LT and composite lines for poles, electric material and hardware, which varies with the pole. Cost items such as conductors, which are common to all poles, were not included in the analysis. The following conclusions can be drawn regarding the selection of poles:

HT Lines

- The 29.5 ft., 391 kg, low cost prestressed concrete pole is the least expensive pole option for single phase HT lines and all types of conductors including Osprey.

- In the case of mole conductors and 3-phase HT lines, the 29.5 ft., 391 kg, low cost prestressed concrete poles is the best option.

TABLE 5 2

COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE AND SINGLE PHASE HT LINES PER KM CLEARANCE : 15 Ft
WIND PRESSURE: 8 lbs /sq ft

NO	DESCRIPTION	CHEAPEST POLE OPTION	COST PER KM* EXCL COMMON COSTS		
			WAPDA SL	WAPDA PSC	LCP PSC
A	THREE PHASE HT LINES				
1.	Mole	29.5 ft. (1)	27,535	16,480	9,331
2.	Squirrel, Gopher and Weasel	29.5 ft (2)	26,213	15,689	10,344
3.	Rabbit	29.5 ft. (2)	27,535	16,480	11,039
4.	Dog	26.2 ft (2)	31,665	16,480	14,416
5.	Panther, Pelican	24.6 ft (2)	46,314	22,050	19,292
6.	Osprey	24.6 ft (2)	49,783	23,764	20,709
B.	SINGLE PHASE LT. LINES				
1.	Mole	29 5 ft. (1)	27,110	16,055	8,800
2.	Squirrel, Gopher and Weasel	29 5 ft. (1)	25,809	15,284	8,800
3.	Rabbit	29.5 ft. (1)	27,110	16,055	9,391
4.	Dog	29 5 ft (1)	27,110	16,055	9,391
5	Panther, Pelican	29 5 ft. (1)	30,417	16,055	10,067
6.	Osprey	29.5 ft (1)	32,640	16,055	10,067

* BASED ON ALLOWABLE SPAN LENGTH

LCP : Low Cost Poles
SL : Steel Lattice
PSC : Prestressed Concrete

29 5 ft (1) : Low Cost PSC Pole. Height 29.5 ft Weight 391 kg
29.5 ft. (2) : Low Cost PSC Pole Height 29 5 ft Weight 470 kg
24 6 ft (2) : LOw Cost PSC Pole. Height 24 6 ft Weight 310 kg

TABLE 5.3

COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE AND SINGLE PHASE LT LINES PER kM IN VERTICAL AND HORIZONTAL FORMATION
CLEARANCE : 15 FT WIND PRESSURE : 8 lbs./sq. ft

NO	DESCRIPTION	CHEAPEST POLE OPTIONS	COST PER kM EXCL. COMMON COSTS		
			WAPDA SL	WAPDA PSC	LCP PSC
A.	VERTICAL FORMATION				
a.	3-Phase LT Line				
1.	Gnat	29.5 ft. (1)	38,830	17,100	11,576
2.	Ant	29.5 ft (1)	38,830	17,100	11,576
3.	Wasp	29.5 ft. (2)	50,751	18,212	15,062
4.	Chafer	29.5 ft. (2)	68,457	24,607	17,227
b.	1-Phase LT. Line				
1.	Gnat	29.5 ft. (1)	38,290	16,560	10,975
2.	Ant	29.5 ft. (1)	38,290	16,560	10,975
3.	Wasp	29.5 ft. (1)	38,290	16,560	12,357
4.	Chafer	29.5 ft. (1)	40,779	16,560	12,851
B.	HORIZONTAL FORMATION				
a.	3-Phase LT. Line				
1.	Gnat	29.5 ft. (2)	38,711	14,530	10,671
2	Ant	29.5 ft. (2)	39,395	13,957	10,349
3.	Wasp	24.6 ft. (2)	66,678	24,989	15,187
4.	Chafer	24.6 ft. (2)	89,775	33,725	18,478
b	1-Phase LT Line				
1.	Gnat	29.5 ft. (1)	28,386	12,849	8,686
2	Ant	29.5 ft. (2)	29,021	12,849	9,933
3.	Wasp	29.5 ft. (2)	39,105	14,448	10,501
4.	Chafer	24.6 ft. (1)	51,054	18,886	12,479

LCP : Low Cost Poles
SL : Steel Lattice
PSC : Prestressed Concrete
29.5 ft (1) : Low Cost PSC Pole Height 29.5 ft Weight 391 kg
29.5 ft (2) : " " " " " 29.5 ft " 470 kg
24.6 ft. (1) : " " " " " 24.6 ft " 265 kg
24.6 ft (2) : " " " " " 24.6 ft " 310 kg

TABLE 5 4

COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE
COMPOSITE LINE PER KM CLEARANCE : 15 Ft.
WIND PRESSURE : 8 lbs./sq. Ft.

NO	DESCRIPTION	CHEAPEST POLE OPTION	COST PER KM EXCL COMMON COSTS		
			WAPDA SL	WAPDA PSC	LCP PSC
A	VERTICAL FORMATION				
1	Gnat + Squirrel	29 5 ft (1)	57,040	34,970	42,418
2	Ant + Gopher	36 ft (PSC)	57,040	34,970	56,698
3	Wasp + Rabbit	36 ft (PSC)	59,208	34,970	56,698
4	Chafer + Dog	36 ft (PSC)	81,339	39,831	61,052
B.	HORIZONTAL FORMATION				
1.	Gnat + Squirrel	29.5 ft. (2)	45,122	28,120	25,077
2.	Ant + Gopher	29.5 ft (2)	42,251	26,112	25,560
3.	Wasp + Rabbit	26.2 ft. (2)	69,382	34,438	40,420
4.	Chafer + Dog	26.2 ft. (2)	95,166	47.147	50.707

LCP : Low Cost Pole
SL : Steel Lattice
PSC : Prestressed Concrete
29 5 ft (1) : Low Cost PSC Pole. Height 29.5 ft. Weight 391 kg.
29 5 ft (2) : Low Cost PSC Pole. Height 29.5 ft. Weight 470 kg.
36 ft (PSC) : Standard WAPDA PSC Pole. Height 36 ft. Weight 1079 kg.

- For three phase HT lines with conductors ranging from Gopher to Rabbit the 29.5 ft., 470 kg, low cost prestressed pole is the least expensive.

- For three phase HT lines with Dog conductor, the 26.2 ft., 364 kg pole is least expensive. For larger conductors (Panther, Pelican and Osprey) the 24.6 ft., 310 kg pole is the best.

LT Lines, Vertical Formation

- For single phase LT lines (all conductors) and three phase LT lines, using Gnat and Ant conductors the 29.5 ft., 391 kg pole is least expensive.

- For three phase LT lines, using Wasp and Gopher conductors, the 9.5 ft., 470 kg pole is the least expen. ve solution.

LT Lines, Horizontal Formation

- In the case of three phase LT lines, the 29.5 ft., 470 kg pole offers the best economy in the case of Gnat and Ant conductors. For Wasp and Gopher conductors, the 24.6 ft., 310 kg pole is the least expensive solution.

- In the case of single phase LT lines, the following poles are least expensive:

  - Gnat : 29.0 ft., 391 kg
  - Ant & Wasp : 29.0 ft., 470 kg
  - Chafer : 24.6 ft., 265 kg

Composite Lines, Vertical Formation

- In the case of 3-phase composite lines, the 29.5 ft., 391 kg pole is the least expensive solution for Gnat + Squirrel conductors.

- For all other conductor combinations, the standard WAPDA prestressed concrete pole using maximum allowable spans will be the least expensive options.

Low Cost Distribution Line Construction

Drastic reductions in cost of line construction can be made by changing the existing pole type for both HT and LT lines, using the existing structures only where their strength provides the longest spans (as in the case of composite lines) and by introducing single phase lines.

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A detailed cost analysis of distribution line construction was carried out under the current study for the following three cases:

- o Case 1 : Standard WAPDA supports
- o Case 2 : Low cost supports
- o Case 3 : Existing WAPDA practice

Under case 1, the maximum allowable span lengths for the existing WAPDA poles were used for calculation of construction cost per km. Under case 2 the low cost structures were used, keeping in view the allowable span lengths, discussed earlier. Under case 3, the existing WAPDA poles and span lengths (440 ft. for HT and 220 ft. for LT) were used. The analysis is given in a separate volume entitled "Detailed Analysis of cost of Distribution Construction". Cost summaries are given in Annex T4, which shows cost of construction of line for the three cases and poles 3 to 14. The wooden poles 1 and 2 were excluded from this analysis.

Cost comparisons for HT and LT distribution cost construction using existing practice (case 3) and improved practice (case 2) for the most economical solution are given in tables 5.5 and 5.6. In the case of LT, only the vertical formations (the existing practice) has been shown. The costs for HT horizontal formation are sligh ly less than those for the vertical formation.

Distribution line construction using low cost poles and optimized spans can result in considerable savings (Table 5.7).

Two case studies of an average village and tubewell (Annex T5), were carried out to determine the range of cost savings. If the spans of existing poles are optimized, the cost of construction can be reduced. However, the savings through conversion to the low cost poles will be much greater than with existing poles. The range of cost savings in relation to the existing practice is briefly discussed below.

Line Cost Savings due to Low Cost Poles

Replacement of the existing steel lattice poles by low cost prestressed concrete poles can result in savings (Table 5.7) ranging from about 33 % for 3-phase HT lines to about 57% for 1-phase HT lines.

If the existing prestressed poles (36 ft.) are replaced by the low cost prestressed concrete poles, the savings in cost of lines will range between about 17% (3 phase HT) and 33% (1-phase LT).

TABLE 5.5

COMPARISON OF COST OF CONSTRUCTION OF 11 kV DISTRIBUTION LINES PER km USING STANDARD AND IMPROVED WAPDA PRACTICE AND STANDARD POLES VS LOW COST MOST SUITABLE POLES

RUPEES

NO	DESCRIPTION	EXISTING PRACTICE		IMPROVED PRACTICE		
		SL	PSC	SL	PSC	LCP-PSC
A	Three Phase 11 kV Lines					
1	Mole	55,916	39,394	45,127	32,813	25,099
2	Squirrel	63,683	47,166	51,380	39,657	34,000
3	Gopher	66,423	49,901	54,116	42,393	36,735
4	Weasel	70,279	53,757	57,971	46,248	40,591
5	Rabbit	83,157	66,635	72,368	60,054	54,319
6	Dog	117,571	101,048	111,543	94,476	93,079
7	Panther	151,376	134,854	162,114	134,796	133,088
8	Pelican	164,438	147,915	175,175	147,757	146,149
9	Osprey	190,559	174,036	205,248	175,958	174,038
B.	Single Phase 11 kV Lines					
1	Mole	51,417	34,894	40,789	28,475	20,644
2	Squirrel	56,598	40,076	44,474	31,210	26,558
3	Gopher	58,421	41,899	44,951	33,763	26,999
4	Weasel	60,992	44,469	48,868	37,145	30,219
5	Rabbit	69,577	53,055	58,949	46,635	39,538
6	Dog	92,519	75,997	81,891	69,577	62,480
7	Panther	115,056	98,533	108,681	90,397	84,283
8	Pelican	123,764	107,241	116,908	100,821	94,564
9	Osprey	141,178	124,656	136,881	118,236	111,979

SL : Standard WAPDA Steel Lattice poles
PSC : Standard WAPDA Prestressed Concrete poles
LCP-PSC : Low cost prestressed concrete poles

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TABLE 5 6

COMPARISON OF COST OF CONSTRUCTION OF 0 4 kV DISTRIBUTION LINES USING STANDARD AND IMPROVED WAPDA PRACTICE AND STANDARD POLES VERSUS LOW COST MOST SUITABLE POLES USING VERTICAL FORMATION

RUPEES

NO	DESCRIPTION	EXISTING PRACTICE		IMPROVED PRACTICE		
		SL	PSC	SL	PSC	LCP-PSC
A	Three Phase 0 4 kV Lines					
	1 Gnat	81,900	49,514	67,256	43,121	36,948
	2 Ant	101,226	68,840	86,582	62,447	56,274
	3 Wasp	142,042	109,657	140,543	104,480	101,997
	4 Chafer	237,680	205,294	255,745	207,105	203,893
B.	Single Phase 0.23 kV Lines					
	1. Gnat	69,582	37,196	55,145	31,010	24,769
	2. Ant	79,245	46,859	64,808	40,673	34,432
	3. Wasp	99,653	67,268	85,216	61,081	56,835
	4. Chafer	147,473	115,087	135,781	108,901	104,683

SL : Standard WAPDA Steel Lattice poles
PSC : Standard WAPDA Prestressed Concrete poles
LCP-PSC : Low cost prestressed concrete poles

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TABLE 5 7

COST SAVINGS DUE TO LOW COST POLES

NO.	DESCRIPTION	COST SAVING w.r.t EXISTING PRACTICE %		
		Steel Lattice Existing Spans	Low cost Prestressed Concrete Existing Spans	Weighted Average *
1	3-Phase HT Lines			
	a. Gopher (35%)	45	26	41.2
	b. Rabbit (25%)	35	18	31.6
	c. Dog (40%)	21	8	18.4
	Weighted Average	32.9	16.8	29.7
2.	1-Phase HT Lines			
	a. Gopher (80%)	54	36	50.4
	b. Rabbit (10%)	43	25	39.4
	c. Dog (10%)	32	18	29.2
	Weighted Average	50.7	33.1	47.2
3.	3-Phase LT Lines			
	a. Gnat (25%)	55	25	49.0
	b. Ant (65%)	44	18	38.8
	c. Wasp (10%)	29	8	24.8
	Weighted Average	45.2	18.0	40.0
4.	1-Phase LT Lines			
	a. Gnat (25%)	64	33	57.8
	b. Ant (65%)	57	27	51.0
	c. Wasp (10%)	43	16	37.6
	Weighted Average	57.3	27.4	51.4
5.	Average Village			
	3-Phase HT Lines (2km) 3-Phase LT Line (0.25km) 1-Phase LT Line (2.0km)	39	16	36.0
6	Average Tubewell			
	3-Phase HT Line, Gopher 0.25 km, Rabbit 0.25 km	39	22	35.6

* 80 % Steel Lattice, 20 % Prestressed Concrete

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Overall Distribution Cost Savings in Village and Tubewell Electrification due to Low Cost Poles

If the existing steel lattice structures are completely replaced by low cost poles, the average cost savings can be about 39% for both village and tubewell electrification.

If the existing prestressed concrete poles are replaced by low cost poles, the average cost savings can be on the order of 16% in the case of village electrification and 22% for tubewell electrification.

Overall Cost Savings in Distribution Line Construction for the Entire Rural Electrification Programme

Introduction of low cost poles can result in about 36% (Table 5.7) reduction in the cost of distribution lines, which account for about 35% of the total cost of construction. In other words, the change over to the cheaper poles can result in cost savings in the order of about 12.5% of the total cost of the rural electrification program.

5.2.1.2 Conductors

The existing range of HT and LT conductors can provide optimum solutions if the changes in conductor sizes are weighed against an increase or decrease in energy losses as a result of a change in the size of conductor. Changes in conductors are options which should be evaluated against the installation of voltage regulators. The conductor selection studies should be made for the economically attainable power factor (0.95). A case study for conductor selection was carried out under this project. The conductor selection optimization can result in substantial life cycle savings. Details of the case study are given in Annex T2.

At present, four HT conductors (Gopher, Rabbit, Dog and Panther) and three LT conductors (Gnat, Ant, Wasp) have been standardized by WAPDA. In the case of HT conductors, Gopher ($25mm^2$) and Rabbit ($50mm^2$) are used for main T-offs and branch circuits. On main lines, Dog ($100mm^2$), Rabbit and Gopher are used. The general rule of thumb is to use Dog for the first 1/3rd of the line, Rabbit for the next one third and Gopher for the remaining line. For main T-offs, Rabbit is the normal choice whereas for smaller T-offs, Gopher is selected. This approach does not necessarily provide the most economic conductor sizes.

Choice of conductor sizes is affected by (1) the power factor of the loads, (2) extent of voltage regulation, (3) cost of energy losses per kWh and (4) the load factor of the feeder. Conductor area which meets the constraints of quality of service (i.e. permissible voltage drop) and offers the lowest present worth of cost over the

life cycle of conductors is the economic conductor area. This analysis must take into account the application of capacitors and voltage regulators. To evaluate the impact of different conductor sizes on overall feeder costs, detailed studies of a rural feeder having mixed loads were carried out under this project. Detailed analysis is presented in Annex T2 and a summary of the results is given in table 5.8.

Analysis of different conductor combinations and applications of voltage regulation shows that the solution which has the lowest capital cost is the most expensive solution over the life cycle of equipment. Incorrect conductor selection can result in considerable financial losses to the utility and worsen the quality of supply. The solution which aims at a reduction of technical losses through better conductors and voltage regulators may not be the most economical. To select the most economical conductor sizes, the cost of conductors, voltage regulators and losses must be minimized in terms of life cycle costs as measured by the net present worth.

With reference to the conventional conductor selection (1/3rd Dog, 1/3rd Rabbit and 1/3rd Gopher on main lines and Rabbit or Gopher on all T-offs), the most economical solution is a different mix of Dog, Rabbit, Gopher, Weasel and Mole conductors.

The optimized solution for conductor selection appears to be (1) to have the largest conductor sizes on the main line to limit voltage drops and losses and (2) to use smaller conductor sizes on T-offs and branch circuits where the demand is low and the choice of a smaller conductor does not result in any significant increase in voltage drops and technical losses.

Although the overall capital investment in the case of the optimized and conventional solutions appear to be the same, the design approach in the case of the former relies upon cheaper branch circuits and more expensive main lines. In the conventional solution, the better conductor is used where it makes an insignificant contribution in terms of loss reduction or voltage quality. In the case of extensions on branch circuits, the use of smaller conductors, such as Mole (10 mm^2) and squirrel (20 mm^2) can result in substantial cost savings in electrification of individual villages.

The question of the choice of conductors for three and single phase HT as well as LT lines needs to be examined with reference to the type of load (individual load, group of loads such as tubewells, villages etc.)

Detailed engineering studies of individual loads, villages, groups of villages, group of tubewells, only tubewell or mixed village and tubewell loads, low or high population and tubewell densities should be carried out to develop guidelines for optimization of costs under different conditions. The cost of losses is an important element in the optimization process. Detailed studies of the methodology of evaluation should to be made.

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TABLE 5.8

ECONOMIC COMPARISON OF DIFFERENT CONDUCTOR SIZES FOR A SAMPLE FEEDER* TAKING INTO ACCOUNT VOLTAGE REGULATION AND CAPACITOR APPLICATION

NO.	DESCRIPTION	UNIT	CONVENTIONAL SOLUTION	MINIMUM ENERGY LOSS SOLUTION	MINIMUM CAPITAL INVEST-MENT	OPTIMISED SOLUTION
1.	Conductor Length					
	a. Dog	%	38.2	53.3	0	44.[illegible]
	b. Rabbit	%	15.1	18.2	0	8.[illegible]
	c. Gopher	%	46.7	19.6	71.5	18.[illegible]
	d. Squirrel	%	0	0	0	9.[illegible]
	e. Mole	%	0	8.9	28.5	18.[illegible]
2.	Voltage regulation kVA	kVA	0	0	0	0
3.	Losses	MWh	46	36	153	42
4	Capital Investment					
	a. Voltage regulator and line cost	Rs	856,339	968,980	469,834	855,68[illegible]
	b. Cost savings	Rs.	0	-112,641	-386,505	+ 65[illegible]
		%	0	- 13.1	- 45.1	+ 0.[illegible]
5.	Cost of energy losses/year	Rs.	45,552	71,832	304,848	84,036
6	Present worth of costs					
	a. Voltage regulator	Rs.(000)	0	0	0	0
	b. Line	Rs.(000)	1,120	1,289	625	1,138
	c. Losses	Rs.(000)	607	479	2,032	561
	d. Total	Rs.(000)	1,727	1,768	2,657	1,699
	e. Cost savings(+)/	Rs.(000)	0	-41	-930	28
	Loss(-)	%	0	-2.4	-53.8	+1.6

* Feeder length : Main line = 10.5 km. T-offs = 4.01 km
Power factor for calculations = 0.95. Voltage regulation = 10%
Cost of energy losses = Rs. 2 per kWh

Detailed engineering and economic analyses of conductor sizes, to determine the optimum choice, must be made a standard part of project design. Based on detailed sample studies, a set of guidelines should be developed for preliminary conductor selection. This preliminary design should thereafter be subjected to rigorous review to choose conductor sizes for a period of perhaps 10 years.

Under conditions of resource constraint, it may not be the best approach to design conductors for demand in year 20, in particular on the branch lines where individual loads can be dealt with on a case by case basis. The quality of supply on the main lines should, in any case, be reviewed on an annual basis to determine the necessary conductor changes.

A strategy should to be developed to determine whether it is more economical to design the main lines for demand in year 5, 10, 15 or 20 and to consider a change of conductor at a later stage.

Case studies of uses of cheaper conductors for electrification of a typical tubewell and a group of villages and tubewells were carried out (see Appendix T5). The application of both three phase and single phase lines were examined. As may be seen from the summary of results (Table 5.9), considerable savings (62% for tubewells and 46% for group of villages and tubewells) are possible, for the cases considered, by installation of cheaper conductors on three phase HT lines. Cheaper conductors in combination with single phase lines result in considerable savings (60% in both capital and net present worth of costs) in the case of tubewells studied, and about 6% (capital cost only) in the case of groups of tubewells and villages. In this case, there are no savings in net present worth of costs (capital and O&M). However, the application of a cheaper conductor is fully justified.

Studies of the choice of demand in year 10 or 20 for design of the distribution lines (Table 5.10) indicate that it is more cost effective to construct the lines for demand in year 10 and thereafter carry out rehabilitation (in terms of conductor replacement or voltage regulation) in year 10 or 15 to improve the quality of supply and reliability and to reduce technical losses.

5.2.1.3 Distribution Transformers

For every area with a certain demand level there is an optimum mix of HT transformers and LT network. Furthermore, the specifications of the transformers can be revised to allow higher or lower copper and iron losses. Case studies of different designs of transformers (see Annex T3) were carried out. Substantial savings in capital investment on the order of 15 to 20% are possible.

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TABLE 5.9

COST SAVINGS THROUGH INTRODUCTION OF CHEAPER CONDUCTORS FOR ELECTRIFICATION OF A TYPICAL TUBEWELL AND GROUP OF VILLAGES AND TUBEWELLS

NO.	DESCRIPTION	COST Rs		COST SAVINGS	
		Existing Standards Practice	Low Cost Conductors	Rs.	%
A.	Three Phase Lines				
1	Tubewells				
	a. Capital*	33,212	12,550	20,622	62.1
	b. Net present worth of losses & capital cost	44,177	16,704	27,473	62.2
2.	Group of Villages and Tubewells				
	a. Capital*	266,356	144,147	122,209	45.9
	b. Net present worth of losses & capital cost	400,973	285,156	115,817	28.9
B	Single Phase Lines				
1.	Tubewells				
	a. Capital*	33,212	13,322	19,890	59.9
	b. Net present worth of losses & capital cost	44,177	17,742	26,435	59.8
2.	Group of Villages and Tubewells				
	a. Capital*	266,356	250,024	16,332	6.0
	b. Net present worth of losses & capital cost	400,973	425,972	-24,999	-6.0

* includes cost of HT lines, and voltage regulator. Line length for tubewell and group of tubewells and villages is 0.5 km and 4 km respectively.

TABLE 5.10

COST COMPARISON OF CAPITAL INVESTMENT LOSSES, AND MAXIMUM VOLTAGE DROPS ON THE BASIS OF DEMAND IN YEAR 5, 10, 15 AND 20 BASIS OF DESIGN WAS DEMANDED IN YEAR 10 DISTRICT OKARA, TEHSIL OKARA GRID STATION GS-9

NO	DESCRIPTION	CAPITAL INVESTMENT Rs (000)	NET PRESENT WORTH Rs (000)			MAXIMUM VOLTAGE DROP %
			Capital	Losses	Total	
1	Design based on demand in yr 10					
	a. Year 0	9,289	12,354	0	12,354	-
	b. Year 5	"	12,354	5,660	18,014	3.5
	c. Year 10	"	12,354	10,139	22,493	7.0
	d. Year 15	"	12,354	17,522	29,876	9.2
	e. Year 20	"	12,354	28,712	41,284	13.4
2.	Design based on demand in yr 20					
	a. Year 0	13,005	17,296	0	17,296	-
	b. Year 5	"	17,296	2,830	20,126	2.9
	c. Year 10	"	17,296	5,070	22,366	3.5
	d. Year 15	"	17,296	8,761	26,057	4.6
	e. Year 20	"	17,296	11,856	29,152	6.7
3.	Conductor change IN year 10	920	+1,220	-8,463	-7,243	

k (11856 + 5070) / 2) - (23712 + 10139) / 2)
= 8463 - 16926 = -8463 .

An analysis of different aspects of distribution transformer design is given Annex T3. In transformer design, the first aspect is the size, which makes it possible to utilize the installed capacity in the system in an effective manner. An example is the installation of a 25 kVA transformer for a load where the actual requirement is 15 kVA and where no other load is available to improve the utilization of the installed capacity. The second important aspect are the transformer losses. Higher losses result in lower capital cost but higher energy losses. The optimum loss level is one where the savings in capital cost are equal (in present worth form) to the cost of losses. WAPDA's standardization of copper and iron losses for distribution transformers needs to be reviewed in the context of rural loads.

Considerable transformer capacity is being wasted in the WAPDA's rural system due to the non-availability of smaller sizes of distribution transformers (5, 10, 15, 20 kVA) which can help in matching the installed capacity with demand. For example, the availability of 5, 10, 15 and 20 kVA transformers could make it possible to connect 5, 10, 15 and 20 HP motors directly through HT lines. This arrangement would result in savings in transformer installed capacity as well as savings in energy losses. Due to the elimination of long spans of LT lines, the quality of supply to the tubewells would also be improved. Detailed engineering studies and surveys are recommended to study the question of matching of transformer capacity with demand.

Compared to the standard 25 kVA transformers (see table 5.11), the small 5-10 kVA single phase transformers will result in capital cost savings on the order of 22%-27%, where two motors are connected to one 25 kVA transformer. The three phase 5-20 kVA transformers will result in savings in capital cost ranging from 7% to about 45%. Single phase transformers of sizes 15-50 kVA will have capital cost reductions ranging between 21% and 51%.

The low cost-high loss three phase transformers of sizes 15-100 kVA can bring about savings in the range of 5 - 23%, the highest savings being in the case of 25 kVA transformers. Savings in sizes 200 - 630 kVA are small (2-7%). The lower capital cost and higher losses were evaluated at a 15% discount rate and 2 rupees per kWh as cost of energy losses. Alternative transformer designs were studied (Annex T3); three sizes (15, 25 and 50 kVA) are shown in Table 5.12. Evaluation of present worth of capital and losses shows that the high loss transformers will be more expensive.

The economic impact of the smaller single phase transformers was studied for sample areas in Punjab (Okara) and Baluchistan (Kalat). The standard three phase transformers were compared with transformers of sizes 5 to 25 kVA. Both capital cost and losses were evaluated. Results of this analysis are summarized in Table 5.13. In both the areas single phase transformers resulted in substantial (36%-38%) savings in capital cost. Savings in net present worth of both capital and losses are about 15% and 26% respectively.

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TABLE 5.11

COST COMPARISON OF STANDARD WAPDA LOW COST, SINGLE PHASE AND THREE PHASE TRANSFORMERS

NO	TRANSFORMER SIZE	CAPITAL COST/kVA Rs.			SAVINGS IN CAPITAL COST %	
		Standard 3-phase	Low 3-ph.	st Low Cost 1-phase	Low Cost 3-phase	Low Cost 1-phase
1.	5 kVA	-	1129	879	+24.7 1/	+26.7
2	10 "	-	695	585	+7.3 1/	+22.0
3.	15 "	-	548	491	+45.2 1/	+50.9
4	20 "	-	495	454	+34.0 1/	+39.5
5.	25 "	600	464	419	+22.7	+30.2
6	50 "	407	351	319	+13.8	+21.6
7.	100 "	299	285	-	+4.7	-
8.	200 "	215	211	-	+1.9	-
9.	400 "	179	174	-	+2.8	-
10	630 "	165	154	-	+6.7	-

1/ Equivalent share in 25 kVA keeping in view the waste of capacity

5 kVA = (25 x 600 / 2 x 5) = 1500
10 " = (25 x 600 / 2 x10) = 750
15 " = (25 x 600 / 15) = 1000
20 " = (25 x 600 / 20) = 750

In some cases, the capacity utilisation may be better than assumed here.

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TABLE 5.12

ECONOMIC COMPARISON OF DIFFERENT LEVELS OF COPPER AND IRON LOSSES IN THREE PHASE DISTRIBUTION TRANSFORMERS

NO.	DESCRIPTION	UNIT	15 kVA		25 kVA		50 kVA	
			Low Loss	High Loss	Low Loss	High Loss	Low Loss	High Los
1.	Losses							
	a. Copper	W	461	568	640	866	1,170	1,163
	b. Iron	W	122	102	123	132	175	243
2.	Energy Loss *							
	a. Copper(25%)	kWh	1,010	1,244	1,402	1,897	2,563	2,548
	b. Iron	kWh	1,069	893	1,078	1,157	1,534	2,130
	Total	kWh	2,079	2,137	2,480	3,054	4,097	4,678
3.	Cost of Losses							
	a. Copper	Rs.	2,019	2,488	2,804	3,794	5,126	5,096
	b. Iron	Rs.	2,137	1,787	2,156	2,314	3,068	4,260
	Total	Rs.	4,156	4,275	4,960	6,108	8,194	9,356
4.	Capital cost	Rs.	9,337	8,873	15,001	11,599	20,362	17,564
5.	Savings in capital %		0	+5.0	0	+22.7	0	+13.7
6.	Present Worth							
	a. Capital (incl. O&M)	Rs.	12,418	11,801	19,951	15,427	27,081	23,360
	b. Losses	Rs.	27,707	28,500	33,067	40,720	54,627	62,373
	Total	Rs.	40,125	40,301	53,018	56,147	81,708	85,733
7.	Savings in net present worth of costs	%	0	-0.4%	0	-5.9%	0	-4.9%

* Load factor

Overall this analysis indicates that the existing sizes as well as specifications of transformers should be reviewed in detail to establish whether the existing stringent specifications of losses are economically justifiable. It indicates that prototypes of smaller three phase and single phase transformers for both 33 kV and 11 kV single phase (phase to phase and phase to neutral) and LT system (0.415 and 0.230 kV) should be developed and tested. Booster transformers should be developed to meet the requirements of voltage regulation in rural areas.

The economic impact of smaller single phase transformer (up to 25 kVA) was studied for sample areas in Punjab (Okara) and Baluchistan (Kalat). The detailed analysis is given in Annex T5, the results are summarized in Table 5.13. Use of single phase transformers in these two areas can result in capital cost savings on the order of % and % respectively.

5.2.1.4 Other Material and Equipment

Single Phase Motors

Single phase motors up to 2 HP are now manufactured in Pakistan. In the past, the need did not arise beyond this rating. Skill exists in the country and the manufacturers can produce single phase motors up to 10- 15 HP. A test has been conducted on the conversion of 2 phase supply to 3-phase for three phase motors. The phases can be split with the help of capacitors or reactors and the motors can be started with this arrangement.

Other Equipment

A detailed review of specifications of other equipment for rural electrification should be made to determine cost saving solutions. Procedures which must be developed include:

- Equipment evaluation criteria
- Standardization of equipment
- Operation and maintenance considerations

5.2.2 Networks

Planning and Design Criteria

At present, there is no universally accepted definition of planning and design criteria for rural electrification. The planning criteria for power distribution as developed under the WAPDA/USAID Power Distribution Program are applicable primarily for urban areas. A number of key issues need definition and detailed examination for Pakistan's rural electrification program:

TABLE 5.13

COST COMPARISON OF CHOICE OF EQUIPMENT IN SAMPLE AREAS IN PUNJAB (DISTRICT OKARA. TEHSIL OKARA) AND BALUCHISTAN (DISTRICT KALAT, TEHSIL KALAT)

NO.	DESCRIPTION	COST Rs. (000)		COST SAVINGS	
		Standard Practice	Improved Practice	Rs.(000)	%
A.	PUNJAB. OKARA				
1.	Capital Cost				
	Transformers upto 25 kVA (conversion to 1-phase)	29,205	18,701	+10,504	+36.0
2.	Energy losses	19,306	16,444	+2,862	+14.8
3.	Net Present Worth				
	a. Losses	128,707	109,627		
	b. Capital	38,843	24,872		
	Total	167,550	134,499	+30,051	+19.7
B.	BALUCHISTAN. KALAT				
1.	Capital Cost				
	Transformers upto 25 kVA (conversion to 1-phase)	36,135	22,110	+14,025	+38.8
2.	Energy Losses. Mwh	23,886	20,176 1/	+3,707	+15.5
3.	Net Present Worth				
	a. Losses	159,240	134,507		
	b. Capital	48,059	29,406		
	Total	207,299	163,913	+53,386	+25.7

1/ Losses have been reduced due to better utilization of capacity

- o Demand levels
- o Economic voltage levels
- o Economic loss evaluation
- o Equipment replacement policies
- o Life cycle of equipment and planning time horizons

Equipment and Material Specifications

Changes in standards and specifications for transformers, structures, conductors, capacitors, voltage regulators etc. can result in cost optimization without compromising the quality of supply and reliability.

Standards, Specifications and Cost Optimization

To illustrate the potential for cost optimization in WAPDA's rural electrification system, a number of case studies were carried out under this project. The results of these studies are summarized in Appendix T5 (cases 1a and 1b). The following areas of cost optimization have been examined:

5.2.2.1 Transmission and Sub-transmission

The key issues in transmission and sub-transmission for rural electrification are

- o Is 66 or 132 kV the most suitable transmission voltage?

- o Is 22 kV or 33 kV the most suitable distribution voltage for use in areas where 11 kV is not available?

5.2.2.2 Grid Stations

Currently, WAPDA uses 66/11 and 132/11 kV grid stations with 5 MVA, 10/13 MVA and 20/26 MVA capacities. Generally these stations are single bay stations with 4-8 outgoing 11 kV feeders. The design of these substations has been standardized and is based on manned operation. In some special cases, unmanned substations have also been constructed.

The average cost of installed capacity for 132/11 kV grid stations is on the order of 1050 Rupees per kVA. In other Asian countries, the cost varies between 370 and 970 rupees per kVA (Ref. 25). The design and configuration of WAPDA's standard 66/11 kV, 132/11 kV and 132/33 kV grid stations should be examined in detail to determine where cost savings can be made. Some preliminary proposals are as follows:

- Examine the design and cost of power transformers for different sizes.
- Evaluate the impact of voltage ratios such as 132/33 vs. 132/11.
- Develop unmanned stations of different sizes using auto-reclosers instead of breakers.
- Examine prefabrication of the substations.
- Analyze construction labor costs.

5.2.2.3 Primary Distribution Voltage

WAPDA's current distribution system is predominantly an 11 kV system, although 33 kV has been used in some areas. The question of selecting a higher primary voltage such as 33 kV has been raised by different agencies on different occasions and a recent study under the WAPDA/USAID Power Distribution Program indicated that 33 kV may be marginally cheaper in some areas. However the use of this voltage has not been examined in detail in any of the distribution planning studies conducted so far and the cost implications for the WAPDA system have not been examined in their proper perspective. For this reason some of the basic issues relating to 33 kV have been clarified here.

The previous case studies of choice of primary voltage either did not include the cost of transmission and grid stations in the cost comparisons, or else the cost savings were not included. The 33 kV system can provide electricity for the same quality of service but at 1/6th to 1/9th the energy losses of the 11 kV system, to an area at least 4-6 times the area served by the 11 kV system. Four to six 132/11 kV grid stations can be replaced by one 132/33 kV grid station, which reduces the cost of grid stations and transmission lines.

Compared to the 11 kV system, the cost of technical losses in the 33 kV system is dramatically reduced, thus resulting in substantial cost savings. The true cost of the these losses and the avoided grid station, transmission, and generation capacity costs have also be examined in the case of a higher distribution voltage. The rate at which the energy losses are evaluated will also affect the cost calculations.

Another important aspect in the design of network configurations for 33 kV is the selection of distribution conductors. As the voltage increases, small conductors can be used. The 33 kV system generally would use cheaper conductors than an 11 kV system and yet have lesser losses because of the high voltage.

Case studies on the above lines have been carried out for sample areas. The analysis shows that 33 kV is an important supply option and must be included in distribution expansion planning and rehabilitation in both new and existing areas. In particular, new areas, which would normally be served by 3-4 conventional 132/11 or 66/11 kV grid stations, are good prospects for 33 kV distribution.

TABLE 5.14
COST COMPARISON OF 33 kV AND 11 kV DISTRIBUTION SYSTEM
IN TWO SAMPLE AREAS IN PUNJAB (DISTRICT OKARA, TEHSIL OKARA)
AND BALUCHISTAN (DISTRICT KALAT, TEHSIL KALAT)

NO	DESCRIPTION	COST Rs.(000)		COST SAVINGS	
		11 kV	33 kV	Rs.(000)	%
A.	PUNJAB, OKARA				
1.	Capital Cost				
	a. Distribution lines	79,015	72,915	+ 6,100	+ 7.7
	b. Transformer substations	66,961	101,520	-34,559	-51.6
	c. Capacitors	3,364	4,037	- 673	-20.0
	d. Voltage regulator	455	3,118	- 2,663	-85.0
	e. Substations	60,000	48,000	+12,000	+20.0
	f. Transmission	94,500	21,525	+72,975	+77.2
	Total	304,295	251,115	+53,180	+17.5
2.	Energy losses	6,329	1,148	+ 5,181	-81.9
3.	Net Present Worth				
	a. Losses	42,193	7,653	+34,540	+81.9
	b. Capital, O&M	404,712	333,983	+70,729	+17.5
	Total	446,905	341,636	+105,269	+23.6
B	BALUCHISTAN, KALAT				
1	Capital Cost				
	a. Distribution lines	68,430	62,856	+ 5,574	+ 8.1
	b. Transformer substations	39,767	59,881	-20,114	-50.6
	c. Capacitors	1,064	1,276	- 212	-19.9
	d. Voltage regulator	1,207	1,045	- 212	-19.9
	e. Substations	30,000	24,000	+ 6,000	+13.4
	f. Transmission	30,000	24,005	+ 6,005	+20.0
	Total	177,218	167,433	+ 9,785	+ 5.5
2	Energy losses				
3.	Net Present Worth				
	a. Losses	23,693	2,227	+21,466	+90.6
	b. Capital	235,700	222,686	+13,014	+ 5.5
	Total	259,393	224,913	+34,480	+13.3

Even conversion of existing 11 kV distribution systems 33 kV substations and 11 kV distribution in existing areas, and 33 kV extensions in new areas, should be examined. The high costs of additional generation and transmission facilities, energy generation and losses make the examination of 33 kV an interesting option.

Preliminary analysis (see Annex T6) shows that 33 kV distribution could result on cost savings in the order of 17-24%. This analysis excludes the savings in avoided generation and transmission facilities due to the reduction in technical losses. Cost comparisons for 33 kV and 11 kV for sample areas in Punjab (Okara) and Baluchistan (Kalat) show that there are overall savings in both capital and net present worth of capital and energy losses.

5.2.2.4 Phase Options

Presently, WAPDA's rural distribution system is based on 3-phase HT (33 kV and 11 kV) and LT (415 V) and single phase LT (230 V) lines. In many other countries, single phase primary distribution is widely used in rural areas where demand is initially low and the economics of single phase are attractive. Both phase to phase and phase to neutral systems are being used. The economics of both 3-phase and single phase systems are governed by the load density and distances.

In the case of small loads and shorter distances, the value of energy losses in a single phase system is offset by the additional capital investment in a 3-phase system. Consequently, 1-phase, 2-wire distribution may be competitive in certain low load density areas. As the demand increases, additional capital investments (e.g. larger conductor size) and losses are required to meet the additional demand. At that time, a conversion to a three phase system may be economic. Thus the question of both selection of a single phase supply system and its conversion three phase requires detailed examination.

A comparison of (1) three phase, (2) single phase, phase to phase, and (3) single phase, phase to neutral, systems shows the following relationships if the three phase system is used as a reference.

	3-phase Reference	1-phase Phase-Phase	1-phase Phase-Neutral
Current per phase	1	1.732	3.0
Voltage drop	1	3.464	6.0
Losses	1	2.000	6.0

The above comparison shows that, for example, the current in a single phase, phase to phase system is 1.732 the current in a three phase system. The high losses in the single phase system require a conductor size at least 2 to 3 times the conductor size in the three phase system.

Although the initial cost of the conductor may be high, single phase transformers will be cheaper than three phase transformers. If the single phase applications are restricted to small loads and shorter distances where the energy losses are negligible, the overall capital investment through single phase applications can be minimized. If resource constraints are a major consideration, the adoption of single phase applications, under the conditions mentioned above, will be a distinct advantage. Both three phase and single phase systems can, therefore, coexist to the advantage of the utility.

In the United States of America, Europe, Australia and other countries, single phase systems are being used extensively. In Australia and Canada, earth is used as a return conductor in a phase to neutral system. In Great Britain, Ireland, Thailand and Indonesia, phase to phase systems are being used. In Thailand, Bangladesh, Indonesia and Philippines, phase to neutral systems are in operation.

Compared to the phase to neutral system, where the cost of grounding may be high in certain areas, the phase to phase solution has the distinct advantage of economy and ease of conversion into a standard three phase system either by the introduction of phase converters or the installation of a third conductor. The cost of transformers for phase to phase systems may be slightly higher than in the case of phase to neutral systems due to the higher insulation level, but the overall advantages of the phase to phase systems, over phase to neutral systems, are overwhelming.

Profitability of single phase systems in other countries is demonstrated by the extent of the existing single phase lines and transformers in the systems. In Ireland, where rural electrification was started in 1946, the target was to extend electricity service to about 400,000 rural houses, of which only 3% were in villages or clusters of more than 20 houses and the remaining 97% were isolated dwellings. Average housing density per sq. km of farm area was 7. The estimated energy consumption per house was 800 - 1000 kWh per year.

The Irish solution consisted of running a 3-phase steel-cored aluminum SCA conductor of area 50 mm^2 between 38 kV/10 kV stations, operated normally with mid point open and sectionalized every 5 km. This three phase system was the backbone distribution system. For T-offs, galvanized steel G.S. wire conductors of sizes 16 mm^2 and 25 mm^2 SCA were used. The branches varied from a few hundred meters with one or two transformers to 20 km having 30-40 transformers with maximum load not exceeding 300 - 400 kVA. The single phase transformers (10/0.22 kV) were of sizes 3, 5, 15 and 33 kVA with 4% impedance, connected to the backbone through fuses and to the branch lines without fuses. The low voltage distribution system consisted of single phase lines with steel- cored aluminum conductors of sizes 25 mm^2 and 50 mm^2. For villages the standard transformer size was 33 kVA, and the low voltage distribution system was 3 wire 440/220 V.

The extent of the single phase distribution system in Ireland can be seen from the following data:

Main 3-phase, 10 kV lines	:	15,000 km
Single phase branch lines	:	45,000 km
Single phase transformers	:	100,000 (No.)
Low voltage lines	:	45,000 km
No. of consumers	:	400,000
Average annual energy usage per customer	:	2,800 kWh

In Ireland, single phase has been satisfactory for all needs. Wherever the need for additional farm power was felt, it was concluded that either the seasonal demands could be met by tractor power or with single phase/three phase converters. However, over the years the need has been felt to replace the 2x16 mm^2 galvanized steel conductors, install internal fuses on transformers, refine drop out fuses, increase the transformer sizes, install voltage regulators to maintain voltage drop on lines (5% on backbone and 1.5% on branch lines), install capacitors, and loop the single phase networks.

Previous studies of single phase applications in the WAPDA system have been restricted by lack of performance data of electric material and equipment for single phase systems as well as the price information. Single phase distribution lines, due to fewer conductors, can have longer pole spans and lighter poles. Furthermore, in the case of loads where single phase can be economical, the use of WAPDA standard ACSR conductors of sizes above 25 mm^2 does not provide a favorable comparison.

If single phase applications are considered for an entire feeder or a grid station area without any discrimination of either load or distance, the three phase system, in its totality, will always be lowered because the cost of energy losses are very high. However, if the branch circuits to connect small settlements or individual loads (such as tubewells) are considered, single phase applications can be economical even in the WAPDA system. A case study of an average tubewell (see Annex T5) shows that the single phase solution can result in about 60% cost savings in terms of capital investment as well as technical losses. A case study of three branch circuits carrying about 800 kW of village and tubewell demand shows that the savings in capital investment using single phase is about 13% over the three phase solution. Correct choice of the single phase solution will depend upon detailed engineering analysis and rigorous economic analysis of the costs and benefits.

It is recommended that detailed studies of electric supply alternatives for individual loads, small settlements, single villages on branch circuits, and clusters of villages/settlements/tubewells should be carried out to determine the correct mix of three phase backbone systems and single phase branch circuits. These studies should be based on maps, accurate demand forecasts, and rigorous technical, financial and economic analysis. Single phase applications can mean substantial savings in WAPDA's rural electrification program.

Detailed studies of local manufacturing of single phase transformers and motors also need to be carried out. Local manufacture of simple voltage regulators and phase converters can contribute to cheaper single phase systems. Prototypes of this type of equipment should be developed locally and tested under standard operating conditions. Sections of single phase lines using different and cheaper conductors need to be constructed and metered to evaluate the performance of the system.

Considerable additional detailed engineering analysis and studies need to be carried out to evaluate and understand the problems in single phase applications and to evolve acceptable economic solutions. Detailed studies of single phase applications should be a part of every distribution expansion project. However, before this stage is reached a great deal of work is required to develop planning criteria, evaluation methodology, equipment specifications and systems application guidelines.

The application of a single phase system on a sample grid station area of Okara in Punjab was studied in detail. The cost comparison (Table 5.15) shows that in the case of individual tubewells, the capital cost savings are about 18% and the savings in net present worth are about 17%. In the case of branch circuits as well as the main lines, the single phase application can result in a 2% savings in capital costs and will be equally costly in terms of net present worth of costs.

5.2.2.5 Low Voltage Distribution

The existing arrangement of service cables can also be changed to a system of multi-service main which can result in substantial savings.

Drastic cost reductions (Table 5.16) are possible through replacement of the bare conductors and structures by insulated twisted cables along the walls. If LT lines with structures are to be used, the existing method of individual service cables should be replaced by service mains and multi-service LT cables.

TABLE 5.15

COST COMPARISON OF THREE PHASE VS SINGLE PHASE HT. APPLICATION IN A SAMPLE GRID STATION AREA IN PUNJAB DISTRICT OKARA. TEHSIL OKARA. GRID STATION GS-9

NO	DESCRIPTION	COST Rs.(000)		COST DIFFERENCE(1)-(2)	
		3-phase 11 kV (1)	3-phase+1phase 11 kV (2)	Rs. (000)	%
A.	INDIVIDUAL TUBEWELLS*				
1.	Capital Cost				
	a 3-phase	65,509	0		
	b. 1-phase	0	53,881		
	Total	65,509	53,881	+11,628	+17.8
2.	Energy losses	54	121	- 67	-124.1
3	Net Present Worth				
	a Capital	87,128	71,661		
	b Energy losses	363	810		
	Total	87,491	72,471	+15,020	+17.2
B	GRID STATION AREA EXCLUDING INDIVIDUAL TUBEWELLS UNDER A ABOVE				
1.	Capital Cost				
	a 3-phase	9,289	8,018		
	b. 1-phase	0	1,458		
	Total	9,289	9,476	+187	+ 2.0
2.	Energy losses	1,521	1,488	+ 33	+ 2.2
3.	Net Present Worth				
	a Capital	12,354	12,603		
	b Losses	10,139	9,921		
	Total	22,493	22,524	- 31	- 0.1

* Group of 3 tubewells connected to the distribution line through extension to the tubewell load centre.

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TABLE 5.16

COST SAVINGS THROUGH INTRODUCTION OF INSULATED CONDUCTORS AND SERVICE MAINS IN LT. DISTRIBUTION IN A TYPICAL VILLAGE

NO.	DESCRIPTION	COST Rs.		COST SAVINGS	
		Existing Practice	Low Cost Practice	Rs.	%
A.	Insulated Conductors				
1.	3-phase LT lines	29,695	26,173	3,622	12.2
2.	1-phase LT lines	69,521	52,345	17,176	24.7
3.	Service connections (250 single phase and three phase)	311,700	260,500	51,200	16.4
	Total	411,116	339,018	72,098	17.5
B.	Service Mains (10 single phase connections				
1.	Aluminum cables	1,650	1,390	260	15.8
2.	Connection boxes, connectors and service masts	2,180	736	1,444	66.2
	Total	3,830	2,126	1,704	44.5

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A case study of a typical village shows that about 17.5 % savings are possible through the introduction of insulated cables. This type of cable was used under the Asian Development Bank Rural Electrification Project. Although initially the material may have to be imported, local fabrication of twisted insulated cable and hardware is possible. Conversion of existing individual service cables to multiple service mains can result in about 44% cost savings.

5.2.2.6 Choice Between HT and LT Distribution

At present, a large number of irrigation tubewells and rural industry have been electrified through LT lines. More than one tubewell or industry shares the common distribution transformer and LT line. This practice results in poor utilization of transformer and line capacity, as well as high losses due to the low voltage. It also is a cause of poor quality of supply to the customers.

In Pakistan, the LT (0.4 kV) lines constitute about 50% of the HT lines (11 kV, 33 kV) and transformer sizes ranging between 25 - 200 kVA are commonly used in rural distribution systems. In the case of larger transformer sizes, the length of LT lines is out of proportion. LT lines are also used extensively to provide electricity to rural small industry and tubewells. This solution often results in overloading of transformers and increases in technical losses due to a high percentage of LT distribution lines in the system. The suitability of using LT lines in different areas is a question which deserves rigorous analysis both in economic and technical terms.

An alternative to existing LT distribution in the WAPDA system is the utilization of smaller single phase or three phase transformers in combination with single phase or three phase HT lines. Raising the distribution voltage from 0.415 kV to 11 kV (26.5 times) will reduce the technical losses to about one seven hundredth of the existing losses. Introduction of more HT lines will also improve quality of supply and reliability. The capital cost in the distribution system will, however, increase.

Illustrative case studies (Table 5.17) of three/single phase HT versus three/single phase LT indicate that in all cases, the HT solution is more cost effective both in terms of capital investment and net present worth of costs. If the evaluation includes the cost of losses and avoided capacity costs, the HT solution is bound to be more attractive in a large number of cases.

TABLE 5.17

COST SAVINGS THROUGH CONVERSION OF EXISTING THREE PHASE LT. LINES INTO THREE PHASE OR SINGLE PHASE HT. AND SMALLER TRANSFORMERS

NO.	DESCRIPTION	COST Rs.		SAVINGS	
		Existing 3-phase LT.	HT.	Rs.	%
A.	Three phase LT.* converted to three phase HT.				
1.	5 HP Tubewell				
	a. Capital	20,762	16,535	+4,227	+20.4
	b. Net present worth (of capital & losses)	28,126	21,994	+6,132	+21.8
2.	10 HP				
	a. Capital	20,762	18,185	+2,577	+12.4
	b. Net present worth	29,673	24,193	+5,480	+18.5
3.	15 HP				
	a. Capital	28,262	19,775	+8,487	+30.0
	b. Net present worth	42,235	26,316	+15,919	+37.7
B.	3-Phase LT.* converted to single phase HT.				
1.	5 HP Tubewell				
	a. Capital	20,762	14,841	+5,921	+28.5
	b. Net present worth (of capital & losses)	28,126	19,742	+8,384	+29.8
2.	10 HP				
	a. Capital	20,762	18,171	+2,591	+12.5
	b. Net present worth	29,673	24,181	+5,492	+18.5
3.	15 HP				
	a. Capital	28,262	21,586	+6,676	+23.6
	b. Net present worth	42,235	28,740	13,495	+32.0

* 0.25 km LT. line.

Formulation of general detailed guidelines for the choice of HT line versus LT in the WAPDA systems requires more detailed engineering studies. Detailed engineering analysis of LT distribution in the WAPDA rural electrification network is not done as a general rule, in spite of the fact that the LT lines constitute such a large proportion of the total length of distribution lines. A major part of the technical losses in the rural system are to be found in the LT system and attention should be given to this aspect of planning and engineering design to reduce overall system costs and improve service quality and reliability.

Case studies of 5, 10 and 15 HP tubewells (Table 5.17) show that the choice of HT line in combination with smaller transformers is a more economical solution than LT lines. The use of single phase HT lines is more profitable than three phase HT lines due to the cheaper cost of line and transformers. Capital cost savings on the order of 12%-30% are possible in the case of conversion of 3-phase LT to 3-phase HT. Savings in capital cost, by conversion to single phase HT lines, can be on the order of 12%-30% of the cost of three phase LT line and distribution transformers.

5.2.2.7 Auto-reclosers and Sectionalizers

The benefits of installing auto-reclosers and sectionalizers should be evaluated in the context of improved reliability and service quality. Auto-reclosers and on-load breakers can also be used for remote controlled disconnection of branch circuits for load management purposes.

No data are currently available within WAPDA regarding equipment fault frequencies and outage times. The installation of auto-reclosers and sectionalizers can, therefore, not be evaluated to determine whether additional investment cost will be justified in terms of improvement in service availability and increase in revenues.

A case study for cost analysis of the installation of auto-reclosers and sectionalizers on a typical rural feeder was conducted on the basis of broad estimates of fault frequencies, repair times, costs and benefits (see Table 5.18). The installation of auto-reclosers and sectionalizers may be justified from the national economic viewpoint. For the electric utility, it is not financially viable. The profitability of both auto-reclosers and sectionalizers must be examined in detail before any system wide application is considered.

5.2.2.8 Meters

Time of use demand, and energy meters and current limiters should be installed to manage the peak demand of the rural system.

TABLE 5.18

COST COMPARISON OF INSTALLATION OF BETWEEN AUTO-RECLOSERS AND SECTIONALISERS ON A TYPICAL RURAL FEEDER

NO.	DESCRIPTION		WITHOUT AUTORECLOSER/ SECTIONALISER (1)	WITH AUTORECLOSER/ SECTIONALISER (2)	DIFFERENCE (1)-(2)
1.	Average fault frequencies				
	a. Below 20 minutes		65	16	
	b. Above -"-		11	11	
	Total		76	27	49
2	Outage time				
	a. Below 20 minutes (@ 0.25 hrs./tripping)		16	4	
	b. Above 20 minutes (@4 hrs.& 2 hrs)		44	22	
	Total		50	26	24
3.	Energy losses (assuming 2000 kW, average demand)kWh		100,000	52,000	48,000
4.	Cost of Losses/year				
	a. Revenue @ Rs. 0.60		60,000	31,200	
	b. Production @ Rs.2/-		200,000	104,000	
	Total Rs.		260,000	135,200	124,000
5	Capital investment				
	In auto-reclosers/ sectionalisers				
	a. 1 Auto-recloser @ 150,000 6 sectionalisers @ 80,000)	Rs.	0	630.000	
	b. Annualised cost @ 15%	Rs.	0	94,500	
6.	Net Cost per year				
	a. National		260,000	229,700	+30,300(+11.70%)
	b. Utility		60,000	125,700	-65,700(-109.5%)

To facilitate meter reading and cost reductions in service connections, the meters for all households should be located on the outside wall of the house. Meter box which has room for connection box for the cables, meter and devices for load management (such as current limiters) should be developed as soon as possible.

5.2.2.9 Capacitors

Capacitor applications can offer the largest benefits in terms of energy loss reduction and system rehabilitation. However, improper use of capacitors can result in increase of losses and deterioration of quality of supply during off-peak hours.

The choice between 11 kV, LT line and motor capacitors should be examined. The efficacy of the mix of capacitors at grid stations, HT and LT feeders, and individual motors should be examined with reference to the peak and off peak load conditions. Detailed examination of the capacitor application issue should be made for rural networks to answer the following questions:

- Capacitor applications on all motors (switched capacitors)
- Extent of LT and HT capacitors based on detailed economic studies
- Location of capacitors on HT and LT lines
- Balance between capacitors on grid station and distribution lines
- Impact of capacitor application at customer, feeder and grid station level on capacitor application program in transmission
- Impact on generators
- Choice of attainable power factor (0.9 or 0.95)
- Penalties for lack of capacitors to customers
- Economics of capacitor application for the customer, LT networks, HT networks, grid station & transmission
- Data and mapping
- Local manufacture

A great deal of work has been done by WAPDA on the capacitor application issue but the questions listed above have not been resolved due to the lack of data such as existing demands, power factor, circuit maps etc.

5.2.2.10 Voltage Regulators

The design and economy of both single phase and three phase lines can be affected by the installation of voltage regulators. Examination of voltage regulation, as part of a feeder analysis for both distribution rehabilitation and expansion, can result in substantial savings in rural electrification investments.

At present, voltage regulators are not being used in the WAPDA system. Automatic voltage regulators are not manufactured locally and are expensive to install and difficult to maintain. The rural system requires a range of inexpensive booster transformers which can be installed on the lines when voltage problems are encountered. Installation of voltage regulators is, however, not the ultimate solution and must be evaluated only as one of the options to improve quality of supply. Other options such as bifurcation of feeders, express feeders, conversion from single phase to three phase, conversion from LT to HT etc. must also be examined.

Presently, the level of analysis in the WAPDA system in these areas is less than desirable. Detailed engineering studies of these issues must be made to develop a reference library for the planning engineer. The methodology must also be made a part of the work order proposals.

5.2.2.11 Other Network Issues

Standards and Guidelines

The existing distribution planning guide, construction standards and guidelines are not suitable for rural electrification systems, as has been discussed in detail in earlier sections. Detailed rural electrification Planning and Design Standards should be developed and should include:

- Rural electrification Planning Guide
- Work Order System
- Rural electrification Construction Standards
- Reference studies and designs for typical areas

Influence of Design Standards on Rural Distribution Costs

A number of factors influence the overall distribution costs. These include (1) equipment specifications (2) planning and design criteria, (3) provision of spare capacity, (4) demand levels (connection policies), (5) constraints in replacement policies, (6) operation and maintenance policies, (7) financial and economic evaluation procedures, and (8) standardization procedures. Detailed studies of these aspects should be made at regular intervals to update the existing design standards.

In the WAPDA system, the statutory voltage variation is ±5% of the rated voltage. In other Asian countries, the limit varies between +5 and -8 for Bangladesh, and ±10 in Thailand. Reducing the permissible voltage variation from -5% to -10% can mean a cost reduction of about 10%. The technical losses in the system due to poorer voltage and the financial loss to the customers at the remote ends of the feeders due to loss of motor life must be considered within the decision to maintain a certain voltage regulation is being made. In reality the voltage conditions in the WAPDA rural system are presently much worse than the stipulated ±5%. A detailed examination of this aspect of distribution design should be made to establish realistic levels.

The current WAPDA practice of ignoring the power factor of small industry and tubewells in rural areas is causing a major waste of distribution, grid station, transmission and generation capacity. Motors with power factors as low as 0.5 may be found in the system; the rewinding of motors in rural workshops using substandard materials can result in very poor power factors and the wrong sizing of motors will also reduce power factors and efficiencies. Suitable statutory limits on power factors of motors (at least 0.9) must be imposed and a program for installation of capacitors on all existing motors must be implemented.

The design of distribution lines in the WAPDA system is currently based on 3% voltage drop in HT lines, 4% in distribution transformers, 3% in LT lines and 1% in service cables, which results in about 11% voltage drop from the grid station to the customer. These design criteria should be reviewed keeping in view the voltage regulation at the grid station level.

The ADB Regional Rural Electrification Survey Study (Ref. 25) recommends the following voltage regulations at different system levels.

Substation Voltage	+ 6.0% (at full load)
HT lines	- 7.5%
Distribution transformer	- 3.5%
LT lines/cables	- 4.0%
Service connection	- 1.0%
Total	-10.0%

Voltage regulation at the grid station is a must for rural systems. Regulation through substation transformer on-load tap changers or HT feeder regulators at the substations can be evaluated. Since this is an important issue, proper economic evaluation of the voltage regulation options must be made.

Voltage conditions can be improved and losses reduced through (1) installation of capacitors on motors (2) matching of motor size to the power requirements and (3) installing capacitors on LT and HT lines. A suitable mix of switched and unswitched capacitors should be determined. The capacitor application study should be made at the customer, LT, HT, Grid station and transmission levels of the WAPDA system.

Service Reliability

Installation of auto-reclosers and sectionalizers on HT lines can result in a considerable increase in the cost of line, which may not be justified for rural electrification networks. The correct decision regarding installation of these devices can only be made on the basis of economic justification. To carry out such an analysis, operational data regarding current and expected fault frequencies and outage times is necessary, but such data is not presently available. Furthermore the value of increased reliability to customers in not known. Studies into these questions should, therefore, be made and a detailed program of recording and evaluating equipment and line outages and repair times should be developed. Auto-reclosers and sectionalizers can be fitted later when loads are greater.

Major areas where cost savings are possible have been discussed in detail in the earlier sections. The improvement of the quality of supply and service as well as cost reduction is possible by a number of other actions briefly described below:

o Meters

A major portion of the distribution losses are derived from faulty meters. A meter test and replacement program should be initiated. The meters that are removed can be recalibrated and repaired or scrapped. This can be organized at Division either with in-situ (portable test apparatus) or by mass a replacement and repair program using a central testing station. This program is likely to be self-financing.

The design and transport of the present meters may not be sufficiently robust and thus resulting in many meters being faulty on first commissioning and remaining so. New methods to reduce this problem can be readily developed and implemented. A study should be done on a statistical sampling basis if necessary to determine the

number of faulty meters in main stores, sub-stores and customers' premises and from this to determine financial cost.

Meter surveillance program must be instituted to guard against (i) widespread collusion between meter-reader and customer to provide wrong readings, (ii) physical interference to bypass meters. This can be done in a formalized structured approach using random selection techniques and thus enabling a quantification of the problem to be solved.

Within the context of an Energy Loss Reduction program in WAPDA (designed by PTAT) there are a number of specific problems concerning RE to be addressed. Electromechanical metering is very susceptible to mechanical damage in transport, stores and installation. It may be cost effective to use more expensive digitized meters to reduce energy losses and O/M charges. In any event, special arrangements should be developed for the handling of meters to reduce incidence of faults.

The meter-reading period should be increased to every two-months while continuing to issue monthly bills to maintain cash-flow.

As discussed in section 3.6.3 above, there should be a correlation between meter reading and consumption against installed appliance and possible connection to other houses.

o Poor Standard of Construction

Another major problem lies in the poor standard of services (the connections between the main network poles and the houses/meters). A program of replacement/refurbishment would reduce unauthorized connections, eliminate faulty joints/overheating and reduce loses. This could be self financing.

o Replacement of Overloaded Equipment

The final stage--and the most costly--in the process of improving service reliability is to replace overloaded network and transformers. This is very important and needs study since present networks are generally below minimum standard.

o Load Management

Tubewells and other motors tend to be oversized due to unreliability of supply and relatively low incremental purchase cost. The power factor of these units will be low due to the load characteristics and the design of the motor. On average it could be estimated that between 15- 20% additional kVA capacity could be released by improving the power factors on these installations to 85%-90%. This would require the customers to pay the costs of fitting suitably sized capacitors on these motors to improve their power factors or alternatively pay low power factor surcharges in the tariff.

Additionally the supply to tubewells could be interruptible for the two-hour peak period. This would improve the load factor and increase the availability capacity to other customers.

The interruptible tariff could of course be readily applied to the industrial tariffs. This could be done as in other countries by fitting time-switches to existing meters and only recording maximum demand during nominated peak hours.

There is very limited scope for load management of the household load in rural areas. Funds would be best spent on load promotion, and education on the efficient use of electricity and reduction of waste.

As already outlined above, there is considerable scope for load management on tubewells/pumps and industry and this can be readily done by having (i) interruptible supply using time switches (ii) an interruptible tariff and (iii) Making power factor correction mandatory. The same thinking can also be applied to the small rural industrial loads. For commercial customers in rural areas there is very little scope other than maximum demand or time-of-day tariffs for larger commercial customers. Load management which includes an energy loss reduction program is very cost-effective.

o Integration of Primary Voltage and Phase Option Studies

The WAPDA report (Ref. 22) recommends that 33 kV be used as the primary voltage on all new rural electrification schemes in Punjab, Sind and NWFP. The Baluchistan Province with low-load density could be supplied 33 kV single-phase as 11 kV would be too costly. The report also recommends that 11 kV be continued as the primary voltage in urban areas and existing rural 11 kV feeders would be retained.

These conclusions are valid but the study assumed that the high- and low-tension network configuration was the same when considering the various options for the primary voltage. Thus the total cost savings were not identified. This study was not integrated with the 3-Phase PTAT study. There is no coordinated, integrated approach to the total RE 33/11/LT supply requirements and nor to develop a network using lower- costs and lower design standards to suit these requirements.

o Phase Converters

Phase converters are expensive but costs could be reduced by consumers using single phase motors up to 3-HP and 3-phase motors with converters supplied for larger motors when required. This is the best solution for WAPDA. These converters could be manufactured locally and the customer would include this as part of his total installation cost. The starter and phase converter can be installed in the same panel.

o Materials Management

The bulk of the material used in RE construction is centrally procured: poles, conductors, insulator, transformers, meters etc. Small items of material, such as bolts, brackets, supports etc. are locally procured.

There is chronic shortage of these major material items which results in

i. Delays in extending supply
ii. Inflated labor costs caused by repeated visits to the job-site.
iii. Low productively and over - staffing
iv. Low morale among personnel

Under the PTAT project, materials management systems are being developed which will improve the situation. The priorities should be to ascertain (i) the extent of this problem (ii) the degree of material shortages (iii) the real cost of material shortages (iv) a priority action plan to improve procedures and establish a management information system for managers on inventories for critical items.

o Technical Standards

The LT outlets on all transformers should be fused to reduce burn- out.

Without connectors there are major problem such as flickers, heating, burnout, energy loss etc. and a special low-cost connector should be developed.

Inexpensive stays and earthing methods should be developed, such as 16 mm^2 galvanized steel conductors.

The feasibility, design, local manufacture and costs of simple voltage regulator 3-phase and single phase (very limited range in kVA) should be examined.

The feasibility of providing cheap reliable power factor capacitor for rural motors up to 15 kW should be established again provide a limited range.

The use of small 0.5 A and 1.0 A current limiters to replace metering for lifeline rural consumers should be examined. Fitting specially-sealed time-switches to starters on tubewells and other motors in rural to take them off-peak should be done.

5.3 Choice of Generation Option

As has been studied elsewhere by the Energy Wing (Ref 32), in addition to the central grid, there are a number of alternative decentralized generation options for rural electrification, such as diesel, hydro, wind, solar, and solid fuels. Some of these options are dependent on the local natural resource base - wind, solar, hydro - while others are more broadly applicable, such as diesel. The decision to use decentralized generation (DG) can be approached by comparison with RE from the grid. The vast majority of villages have been and will be electrified from the grid. Therefore, the attractiveness of DG as an expenditure of RE funds should be compared to the returns attained from grid-based electrification. As presented in Chapter 4, the village ranking approach is based a benefit-cost criterion. The criterion for DG should be the same. Once village rankings of benefit/cost ratios based on the central grid have been developed, an approximate benchmark B/C ratio can be estimated which is the lowest B/C ratio electrified from the grid and is used below in the evaluation of DG options. It is crucial to note that this B/C ratio would be different from the one used in the examples in Chapter 4 because it would be based on total electricity supply costs including long-run marginal costs for generation and transmission from the grid.

The first stage of evaluating DG options is based on whether the village(s) will ever be part of the national grid. This decision could be based on either the RE district master plans (that will continually be updated) or consideration of the comparative economics of a "special" extension of the grid. The extension should start from the expected extension of the grid in order not to bias the analysis against the grid. If the DG option is lower cost than the grid, then the village(s) can be assumed not to be part of the eventual grid. Such results should be checked with the distribution planning group for that area.

If the village(s) will never be part of the grid, then the appropriate comparison is between the B/C ratio for the village(s) using DG and the central grid B/C ratio including generation and transmission costs as discussed above. Villages with higher B/C ratios for DG options than grid-based villages can be electrified using DG. In this way the returns from RE using DG are as good as those from grid RE. One issue which remains is whether the RE fund will receive the additional monies needed to cover DG generation costs since grid generation costs are generally covered by non-RE budgets.

The option for electrification using DG should be available for all villages whether they will eventually be part of the grid or not. Since complete RE will take time to achieve, villages that lie far from the grid but would eventually be part of it should have the opportunity to be electrified using DG if they or a cluster of them have an attractive B/C ratio.

Non-Planned Electrification from the Grid

As to the categorization of villages with regard to their potential electrification from the grid, such information will gradually be collected as the village data base is refined and the district master plans for electrification are updated. For each village not expected to be connected to the grid, the needed information would be: its distances from the ends of the planned and existing grid; a list of villages which lie between it and the expected grid; and a list of villages that are located within 20 miles.

This information would be used to calculate the cost of grid-based and isolated diesel-based generation for each of these villages. This would be in addition to the above calculations perfomed for those villages with renewable energy options. The comparison of the grid with diesel would be similar to that performed in the Energy Wing report (Ref 32) on decentralized energy options. For grid electricity, a table of estimated costs would be developed including grid costs as a function of the basic grid cost discussed under the renewable section above, and the cost of the extra extension of the distribution system beyond that planned. As with the other grid costs, the unit cost of this extra extension is in turn a function of the level and load factor of demand to be supplied by this line. Likewise the cost of diesel generation will depend on the level and load factor of demand as well as the delivered price of diesel fuel to the area.

The calculation of the grid-based electrification cost for these remote villages is complicated by the need to examine the electrification of a group or cluster of villages in order to capture economies of scale for the distribution system. This is the same issue discussed above, regarding the village ranking criterion as a benefit/cost ratio that is dependent not only on the distance from the grid but also on the location of nearby villages.

This comparison should be based on grid costs that incorporate the eventual extension of the grid and not on the existing extent of the grid. If this is not done, the grid's transmission and distribution costs will be over-estimated if the economics of the grid option does not take into consideration all of the demand that could be served by the extention of the grid.

A complication arises if the DG unit costs are more than those from the grid while the DG B/C ratio is better than the grid benchmark, the grid might be extended to this area soon. This situation could arise if the villages with the DG option have higher benefits than the average village benefits being reached by the grid. If the grid will arrive soon, the DG option should be rejected. But if the grid will not be extended to this area soon, a judgemental process could be considered to still consider the DG option if the grid will not reach the village(s) for a substantial time. Under this condition, electrification using the DG option may be considered since the B/C ratio is better than the grid benchmark B/C ratio even though in the future the B/C ratio would be higher when the grid arrives.

In the case of diesel DG, an interesting opportunity arises even if diesel is more expensive than the grid. Where the diesel B/C ratio is higher than the grid benchmark, it would then be reasonable to electrify village(s) using diesel. As the grid expands and villages being served by diesel are connected, the diesel generating equipment can be shifted to other locations thus making use of village distribution and connection equipment already in place. This approach is applied in Malaysia, and can be considered for any DG option that can be transferred to another site.

One general policy issue which has not been addressed and cannot be adequately done so in this study is the possibility of permitting private DG where the tariffs are set in the private sector. In this way, if a private generator can find buyers at higher prices than the standard tariffs, private generation is permitted. There are a number of issues that need to be addressed as part of considering such a policy, such as consistent national tariffs. Further study of this possibility is obviously needed if it is to be considered seriously.

Even though much of the DG analysis is location-specific, in the next subsections, some general examination of the relative costs of DG versus the grid are presented. The general conclusions are that diesel and hydro have some good potential while wind is less likely to be attractive and solar seems quite expensive. It must be repeated that such conclusions are only indicative, and location-specific analysis is needed as part of the RE planning process.

Diesel Generation

In comparison to most generation technologies, the capital cost of diesel power generation is low (Rs. 5000 per kW), but the relatively short life of the diesel generation plant can nevertheless result in high annualized capital costs. Furthermore, the operating, maintenance and fuel costs are high. In remote areas with poor communications, both repair and maintenance and supply of fuel and lube oil may cause disruption in generation if suitable institutional arrangements are not made.

Photovoltaic Systems

A number of photovoltaic systems have been constructed in Pakistan as demonstration projects. The current cost of photovoltaic systems is in the order of Rs. 138,000 per kW peak power. At this cost, despite its low recurrent costs, photovoltaic systems appear to be economically viable only in exceptional situations.

In the case of individual households, with low demand (such as 0.08 to 0.10 kW), the relative economics of supply from photovoltaic for individual households may prove to be better than those of the central grid. The photovoltaic panels must be supplemented by inverter/battery systems to meet the lighting and fan loads in the evenings.

Wind Generators

The wind generators present an option which may be attractive in areas where wind velocity distributions are within acceptable limits. The cost of wind generator systems is in the order of Rs. 35,000 per kW, which is comparable with the central grid cost of generation, transmission and distribution (area level) per kW. Wind generators may, however, not be adequate to meet the total requirements and hybrid wind and diesel systems may have to be considered.

Microhydro and Small Hydro

A large number of microhydro sites are available in Punjab, Sind, NWFP and Azad Kashmir. Even in Baluchistan some isolated plants can be put up on rivers where perennial flow is available. It is estimated that small hydro projects in these three provinces may offer electric power potential in the order of 500-600 MW. The relative economics of small hydro, both low and high head, are good and the cost of generation ranges between Rs. 25,000 and Rs. 30,000 per kW. Taking into account the fact that the need for transmission lines and voltage transformation does not arise in the case of these projects and the energy losses are relatively low (only in local distribution), the small hydro projects offer one of the most attractive decentralized options.

Microhydro and small hydro plants can be integrated into the WAPDA grid in a large number of places in Punjab and Sind, In northern areas and Azad Kashmir, a more isolated operation will be necessary. The economics in both cases are attractive.

Cost Comparison of Decentralized Options

A number of case studies were carried out to analyze the illustrative economics of diesel, solar, wind, microhydro and central grid for electrification of (1) an illustrative tubewell and (2) an illustrative village and (3) an illustrative area. The prices were based on available information from other studies and recent documentation. The village and area characteristics were based on the sample areas studied under the current study. Details of these case studies are given in Annex T6.

Tubewell for Irrigation

In the case of a tubewell for irrigation, microhydro, the grid, solar and wind are more expensive than diesel engines in Punjab. The best decentralized option for the tubewell is diesel engine. However, as discussed in Chapter 3, with high utilization of the tubewell and off-peak use, the economics will be different and could be in favor of the central grid.

Village and Area

For village electrification in Punjab, the central grid and microhydro are attractive options. However, diesel generation must also be evaluated seriously in all cases where the cost of electrification through central grid is above average or the grid will not be installed.

5.4 Maximizing Local Procurement of Material and Equipment in Pakistan

A shift to new technical options in equipment and design may require that initially selected distribution material, such as steel wire for prestressed concrete structures, hardware for distribution line construction, single phase transformers, voltage regulators, capacitors, meters, etc. is imported. Capabilities, however, exist within the country for local manufacturing of all major items of the RE distribution system. An increase in the existing manufacturing capacities will be essential in certain areas such as poles, transformers, voltage regulators, meters and capacitors. A detailed survey of the existing manufacturing capabilities of each supplier/manufacturer should be made and plan for enhancement of the existing capacity should be prepared as soon as possible based on estimates of expected equipment needs. This study will be essential for evolving strategies for maximizing local manufacturing of distribution material. One immediate issue is the need to expand local pre-stressed concrete pole manufacturing capacity. In addition, to expedite the relationship between local manufacturers and WAPDA, material procurement procedures need to be streamlined so that purchase orders can be placed well in time and at regular intervals.

Most of the distribution material is already procured locally by WAPDA. International competitive bidding (with price preference for Pakistani suppliers) is common on donor funded projects. To obtain competitive prices, this practice has been effective on distribution projects, where the bidding was open to all countries. In the case of restrictive bidding (donor country and Pakistan only), the prices, generally, tend to be higher than those under international or local procurement. It is recommended that as far as possible WAPDA should use international bidding for all major items of material, though studies are needed to devise the specific level for Pakistani price preferences. Restrictive bidding should be confined to only minor items to maintain competitive prices among commodities made in Pakistan.

5.5 Economic Relationships Among Electricity Subsectors

Investments in the power sector cover expansion and rehabilitation in (1) generation, (2) bulk transmission (220 kV, 500 kV) and related substations, (3) secondary transmission (132 kV and 66 kV), (4) grid stations (132 kV & 66 kV) and (5) distribution (urban and rural). Less conventional but gaining attention are investments in load management and energy conservation. The current method of allocation of funds to the different sectors is based on natural growth, special considerations to completion of ongoing projects, and additional emphasis on growth of certain subsectors such as rural electrification.

In 1972 the share of gross fixed assets in operation for the three subsectors (generation, transmission, distribution) was about 43%, 18% and 39% respectively. In 1987, this distribution (provisional) was about 35% generation, 32% transmission and 33% distribution respectively. The number of villages electrified per year during the past 10 years has ranged between 1181 (1980/81) and 3405 (1986/87). The share of rural electrification and the number of customers to be connected has also varied considerably. A current critical issue is the short-fall in generating capacity as evidenced by outages and loadshedding that has been estimated to approach 20 percent of the total peak demand. To address this generation need there are several proposed projects aimed at bringing on-line over 1,000 MW from the private sector during the 7th Five Year Plan.

The allocation of resources within the electricity sector in a conventional analysis is driven by the demand for electricity This demand is influenced by government policy on tariffs and the availability and pricing of other energy products. In a stable and large power system, this allocation of resources among the subsectors is driven by the need to keep the needed technical balance between generation, transmission, distribution, maintenance, and load management. On the other hand, in the growing and smaller systems of most developing countries, demand is limited by the availability of electricity, and there still remains a large potential demand for electricity. Such demand is also often driven by subsidized prices for electricity. Furthermore, on the supply side, investments are very lumpy because of large economies of scale in power equipment. Financial and implementation capabilities are often stretched to the limit to try to meet potential demand, and these capabilities vary by subsector. The resulting situation is a power system whose balance between its subsectors is continually shifting. As major investments come on-line, the capacity in one subsector may exceed the capacity of the other subsectors; in growing systems, this is unavoidable. Because of this fluid situation, the economic relationship between the different subsectors in terms of the relative importance of investment, is continually changing. Obviously, good system planning coordinated with policy development attempts to maintain balanced relationships, but with large projects and the continual changes in demand, the timely implementation of investments is difficult. Continual short and long run planning is necessary to make adjustments.

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The allocation of resources among the different electricity subsectors requires detailed study of the benefits and costs of the full spectrum of possible investment options in these subsectors. Then the results must be viewed in the context of government policies about the increasing reliability and availability of electricity.

The benefits of the potential investments can be estimated based on considering the different power sector goals such as service to new customers, reliability for existing customers, and cost reductions. The returns to each of these goals is different. The value of electricity for service to new customers is their willingness to pay. The value of reliability is usually quite high as it is based on what is called outage costs or the cost of unserved energy. The value for meeting unserved energy has been found to be higher than the willingness to pay because of greater losses in productivity or greater inconvenience to households when one is already dependent on electricity ("The Financial and Economic Impact of Power Interruptions and Load Shedding in the Industrial Sector of Pakistan, Draft, March 1987, Rev. 1, Ebasco-AEPES-ITECO Joint Venture). The value of cost saving measures is simply the resulting decrease in supply system costs.

Each of the possible subsector investment costs can be evaluated against their possible benefits. Depending on the condition of the power system, generation investments will have different mixes of benefits. If generation is short, then the value could be at unserved energy or outages costs; if the system is near balance, then the value is the willingness to pay; if there is excess capacity, then may be the value of fuel savings. Energy conservation or load management could be valued at the avoided cost of new generation. System rehabilitation can be valued based on cost savings, increased reliability, or service of new customers depending on the situation. Technical loss reductions can be viewed as cost savings. (Non-technical loss reductions have no additional economic benefits because such electricity is already providing economic benefits to consumers even though not financial benefits to the utility.)

The analysis would need to consider the scope for investment in the different areas. For example, the scope for investment in reliability is strongly dependent on the level of required improvement in reliability. In situations where there are many outages, the size of potential investment is large. The cost of reliability varies tremendously depending on the system. Furthermore, in Pakistan it varies from the cost of new generation to the cost of distribution rehabilitation.

It is only by comparing the results of this analysis that the relationships can become apparent. Though it is reasonable to conclude system rehabilitation and greater reliability look like the most attractive choices in Pakistan currently. In any case this economic analysis has to be tempered by social and political goals. To the extent that electricity is viewed as a social goal, the value of supply to new customers rather than better reliability of existing customers may have a higher socio-economic return. Another issue is the financial impact of the different investments as the returns to the utility via tariffs may vary from the economic or socio-economic returns. In addition the implementation capabilities and the comparative advantages of the private and public sectors in the different subsectors may differ.

Extensive studies, analysis and sectoral information are required to establish the relationships outlined above. In view of this study's limited resources, such quantitative analysis could not be performed. Nevertheless, detailed analysis along the above lines is recommended.

5.6 Summary

The policies with respect to technical designs and standards and supply alternatives must reflect technical options evaluated in the light of economic costs and benefits. These policies should achieve a goal of finding Pakistan solutions to the problems of RE in Pakistan by drawing as much as possible on the past experience both in Pakistan and other countries which have addressed similar problems.

WAPDA's existing rural distribution network is based on the choice of 11 kV as the primary voltage, extensive use of steel lattice structures for construction of both primary and secondary lines, three phase transformers ranging between 25 and 200 kVA and separate service cables to each customer. An extensive network of low tension distribution lines is already in existence. The networks have high technical losses and poor service quality and reliability. This is a high cost network compared to many other countries and an alternative solution has to be found.

In this connection, the main areas studied include the choice of a higher (33 kV) primary distribution voltage, introduction of single phase option on all branch lines, selection of conductors on the basis of economic criteria and demand in year 10, reduced length of LT lines, utilization of more approximately sized transformers, which can be justified in economic terms, introduction of smaller single phase transformers, multiple service cables and low cost prestressed concrete poles. The current movement in these directions by WAPDA should be supported.

Selection of 33 kV as primary voltage will result in overall cost reductions in capital investments in transmission, grid stations and distribution network expansion in spite of the fact that the 33 kV distribution network is more expensive than 11 kV, but considerable savings are possible in the costs of transmission, and the reduction of grid station and distribution losses.

The single phase option is economically viable on all branch lines. This option is more economical than the current 3-phase arrangement especially for electrification of individual loads such as tubewells. Replacement of 3-phase LT lines by single phase HT lines (specially 33 kV) in combination with phase converters for three phase motors is an attractive solution that results in substantial cost savings and should be examined in detail.

Smaller single phase transformers can be useful in avoiding waste of transformer installed capacity and reduction of losses. Multiple service connection cables offer another cost saving solution.

The existing steel lattice structures unnecessarily increase the cost of distribution lines. The existing prestressed concrete poles are not the optimum poles for rural distribution expansion. Introduction of low cost pole options can result in cost reductions on the order of 35%. Coupled with cheaper conductors used for 33 kV, the overall cost of HT distribution line construction can be reduced by a total of about 50%.

Application of a new cost effective approach, using the above outlined measures, can result in cost reductions close to 40% of the total capital investment, as may be seen from the application in a sample area in Pakistan.

The major cost savings (+), as well cost increase (-) in the sample area, were as follows:

o Transmission & grid stations	+ 55%
o HT distribution lines	+ 61%
o Distribution transformers	- 14%
o LT lines	+ 28%
o Multiple service connection cables	+ 15%
o Regulators and Capacitors	- 87%
- Overall Cost Savings (weighted average)	+ 38%

These savings can be brought about by the introduction of 33 kV three phase (main lines) and single phase (branches) HT distribution lines, 5-25 kVA single phase transformers, multiple service cables, low cost prestressed concrete structures, 132 kV transmission lines and 132/33 kV grid stations.

From these studies it is now possible to prepare preliminary Technical Instruction Manuals outlining the new materials and methodology for introduction of the New Approach to Rural Electrification. In order to gain momentum, work on preparation of detailed technical specifications, product descriptions, standards, guidelines and procurement documents for the new equipment (33 kV, single phase smaller transformers, low cost poles etc.) and materials, must be started immediately.

One of the most important conclusions of the study is that WAPDA should immediately stop further procurement of steel lattice structures. The existing WAPDA and private sector prestressed concrete pole manufacturing capacity should be increased on a crash basis to meet the total requirements of distribution construction. The existing suppliers of steel lattice structures may either be encouraged to utilize their production capacity for transmission line towers or put up prestressed concrete pole manufacturing plants.

Furthermore, there are major opportunities for the private sector in Pakistan for manufacturing of single phase transformers, voltage regulators, phase converters and power factor correction equipment.

To implement and update the new technical standards and guidelines on a continued basis, the capability within WAPDA Distribution must be developed.

In summary, the policy changes needed include:

1. Immediate issuance of a set of preliminary technical standards and guidelines to the AEBs to facilitate the achievement of cost reductions of 30 percent or more;

2. The incorporation of these technical guidelines in the area planning, costing and selection procedures and also in the work order implementation procedures for RE village/settlement investment project preparation and execution;

3. The new rural electrification standards should be implemented within FY 1988/89 for at least a part of the GOP financed and the entire donor funded rural electrification program; and

4. Start of ongoing further studies to develop a final set of technical design and standards guidelines for rural electrification in Pakistan that can be readily implemented at the AEB Division level staff.

Chapter 6

Data and Studies for Rural Electrification Planning

6.1 Introduction

This chapter presents an overview of the data, projects, and studies that are required for rural electrification planning. The first section is a brief description of the comprehensive data base that will be used for diverse applications, including demand analysis, accounting, and village selection. The second section is a summary of the studies and projects that are necessary components of RE planning, both for immediate implementation and for long-term monitoring and evaluation. The last section describes the sources of data that were used in the analyses for this study.

Descriptions of the data bases (existing and to be developed), studies and some of the projects required appear in Appendices L and M.

6.2 Required Data Base

The long-term objective for WAPDA will be the establishment of a totally integrated data base which will be used at various operational levels for all customer-related activities: billing, meter reading, accounts, load research and analysis, technical analysis, demand analysis, analysis of RE benefits, and village selection. A crucial part of this data base development will be in the form of a comprehensive village/settlement data base.

For this data base, basic data need to be collected for all of the villages/settlements in Pakistan, to facilitate decision-making in the first years of this program. These data should include the numbers of tubewells, numbers of rural industries, numbers of households and their distributions of income, numbers of commercial and other consumers, geographic location (as integrated with the mapping effort), electrification status, (if electrified) the present usage patterns of electricity, and as-built maps of existing distribution system as well as future distribution expansion plans.

Many of these data are already or will soon be available in the WAPDA Master File. It contains meter records from every connection, and is updated monthly. This will reduce the amount of primary data collection required, and will help to establish the beginnings of the village data base.

The data base developed by PTAT and USAID is updated annually. It contains data on the electrification status of villages and settlements, and the identification and sizes of feeders. A locational data base is also required, which includes the locations of all settlements and villages, distribution lines and equipment on existing feeders, and grid stations (as well as their available capacities) with map-oriented grid coordinates and future expansion plans.

Data that are not available from the WAPDA, PTAT and locational data bases must be collected from village and household surveys. These surveys will include energy consumption and expenditures, income or wealth measures, willingness and ability to pay for electricity, and through analysis of the data, the impacts of RE on employment and income distribution.

Eventually, every settlement/subvillage that is considered for electrification should be surveyed to this level of detail. Data are also required regarding electrified settlements/subvillages. This is impractical in the opening phases of the planning effort. A viable compromise must be reached between the need for accurate data and scarcity of resources for data collection. This compromise should initially take the form of cluster samples, whereby the data from several villages will represent those from all of the villages in a particular district or tehsil. At a minimum, households should be completely surveyed in one electrified village and one non-electrified village, in every district or tehsil. During the period when detailed distribution mapping is carried out, the existing as-built maps to scale 1:50,000 available with WAPDA sub-divisions may be used. Until new area rural electrification plans are prepared, the existing District Rural Electrification Master Plans can be used and modified where necessary. A review of the secondary transmission and grid station expansion plan will, however, be necessary.

6.3 Necessary Studies, Preparatory Work and Data Base Development

The earlier chapters of this master plan have indicated the need for changes in many of the policies and approaches of the rural electrification program. All of these changes cannot be initiated instantaneously; a number of further studies need to be conducted and a detailed implementation strategy should be developed. However, it is important that steps be taken to implement those particular studies and changes that are possible in the immediate future pending the establishment and staffing of the new organization structures proposed (Chapter 2). These studies will include some that are necessary as preparatory material to support the ongoing implementation of the master plan by the new organization within the framework of the new policies, plans, systems and procedures.

Within this framework, it would be consistent for any and all RE capital expenditures financed under the USAID project to be done in accordance with the criteria and approaches outlined in this plan. Thus the application of the recommended planning procedures to actual project selection, design and execution in the field and all other project plans (whether funded internally and externally) should be developed within the new framework as per the schedule discussed in Chapter 7.

The needed preparatory work and studies are outlined below as well as some comments on the needed time frame. These studies and information are organized in the following groupings:

A. Project Implementation Strategies and Preparatory Work;

B. Technical and Cost Manuals

C. Area Planning Design and Selection Procedures

D. Development of Rural Electrification Expansion Plan

E. Geographic and Demographic Settlement/Village Information;

F. Benefit Studies;

G. Tariff and Related Studies;

H. Technical Equipment Options

Specific efforts in each of these categories are outlined below. Each of the efforts is further categorized in terms of its priority:

- o Immediate - within the first 3-4 months of the plan;
- o Intermediate - within the first 5-7 months; and
- o First Year - within the first twelve months.

A. <u>Project Implementation Strategies and Preparatory Work</u>

Immediate

1. Prepare a strategy for initial work orders and capital expenditures. This will include: where to start; how to use as mechanisms for initial institutional change and strengthening; the choice between expansion and backfill; the modifications that are needed in the work order system and how best to use it.
2. Assist in setting priorities, preparation of a detailed execution plan for studies, and preparatory work below.

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3. Design and initiate the tubewell load management demonstration program:

Intermediate

4. Implement the tubewell comparative demonstration and evaluation program.
5. Provide assistance with studies and preparatory work for efforts described below.

First Year

6. Initiate plan for 5 year tubewell load management retrofit program.
7. Develop a framework and design for ongoing monitoring and evaluation work.
8. Provide assistance with studies and preparatory work for efforts described below.

B. Technical and Cost Manual Preparation

Immediate

1. Prepare a preliminary technical standards and design manual.

First Year

2. Prepare and disseminate the finalized technical standards and design manual.

C. Area Planning Design and Selection Procedures

Immediate

1. Prepare a preliminary area planning and village selection manual.

Intermediate

2. Prepare the first revision to the benefit parameters for the area planning and village selection manual.
3. Review the provincial development objectives, and establish preliminary new provincial-to-district/tehsil allocation procedures.

First Year

4. Revise area planning and village selection manual including examination of regional variations.
5. Conduct first training course (in-country) for WAPDA in area planning and village selection exercise.
6. Analyze alternative federal-to-provincial budget allocations, and continue work on provinces-to-districts allocation procedures (see item 3 immediately above)

D. Development of Village Specific Rural Electrification Expansion Plan

Intermediate

1. Select, prepare least cost expansion plan, and estimate costs for the electrification of about 750 villages based on the new procedures.

First Year

2. Select, prepare least cost expansion plan, and estimate costs for the electrification of about 5000 villages based on the new procedures.

E. Geographic and Demographic Village/Settlement Information

Immediate

1. Establish the map coordinates of all grid stations, feeders, and settlements/villages.
2. Estimate the numbers of potential customers of all types for all settlements/villages drawing primarily on existing data sources: census, prior surveys, studies by other Federal or Provincial agencies etc.
3. Design a sample survey to supplement item 2 immediately above to analyze relationships within selected settlements, for generalization to other settlements.
4. Survey selected settlements as part of physical survey efforts.

Intermediate

5. Survey selected electrified settlements/villages to study the demographics of unconnected households (maybe immediate if backfill is to be emphasized).

First Year

6. Conduct ongoing selected sample surveys and analyses of existing data to better understand the relationships between the numbers of non-household customers and predictive variables - population, distance to market town, agricultural system type etc.

F. Benefit Studies and Related Preparation

Immediate

1. Conduct selected surveys and analyses of secondary data (as extensions of procedures initiated in this study, e.g. usage and payments in small private generation systems, to study household willingness to pay, ability to pay, and existing energy use; also conduct a preliminary study into the data requirements to design low income lifeline tariffs.

2. Conduct limited kerosene use (including lamp type) and price surveys, included test of lamp efficiencies.

Intermediate

3. Initiate load research/cross sectional studies from last year's computerized records, and selected time series analyses from secondary non-computerized data to examine actual use levels and load growth over time by region, income, etc.
4. Conduct demand and load research with selected surveys of electrified villages.
5. Develop survey instrument and conduct survey pretests for impact studies (see item 6 below).

First Year

6. Conduct surveys to measure the impact of RE on:
   (1) complementary investment relationships
   (2) forward and backward linkage evidence, focusing on rural industry, education/literacy, market access factors, employment and income distribution impacts, and commercial establishments
   (3) sex roles in households, agriculture, and small industry.
7. Conduct a study of diesel and electric tubewell user operations to understand actual costs (e.g. labor, efficiencies, rural HSD prices) and cash flow differences, and to determine effects on crop system choice and indirect benefits.

G. <u>Tariff and Related Studies</u>

Immediate

1. Study the design of tubewell tariffs in terms of:
   i. load managed tariffs;
   ii. higher charges for tariff D;
   iii. eliminating category D-1;
   including (a) analysis of connection financing (loans) to coincide with the elimination of subsidies and (b) analysis of provincial/region and cropping pattern impacts.

Intermediate

2. Study low income household lifeline, current-limited rates, including connection financing issues to ensure affordability and support high penetration requirements (based on study F.1 above).

First Year

3. Study general rate increases for other households and rural industry (coordinate with main tariff study, examine provincial differences).
4. Study connection financing for customers except low income and tubewell customers covered in above studies to ensure affordability to support high penetration requirements.

H. Technical Equipment Options

Intermediate

1. Prepare plan for selection, development and manufacturing of new poles, distribution transformers, and meters.

First Year

2. Prepare detailed engineering design for new low cost poles, transformers, and meters; develop prototypes, and pilot field test.
3. Prepare plan for selection, development and manufacturing of other RE equipment such as conductors, voltage regulators, and capacitors. (Undertake equivalent study to H.2. for this equipment in second year)..

6.4 Data Bases for Study Analyses

The data required for the preliminary analyses performed in this study fall into the following categories:

1. Village Selection

   a. Economic and financial parameters
   b. Benefit and demand estimates
   c. RE electricity cost estimates
   d. Village geography and demography
   e. National to district investment budget allocation basis
   f. Intensification
   g. As-built distribution maps
   h. Least cost distribution expansion plans

2. Tariffs and Subsidies

   a. Willness-to-pay and ability-to-pay estimates
   b. Tariffs
   c. Demand patterns
   d. Financial and economic costs of total electricity supply

3. Technical Specifications, Design Parameters and Revised Costs

6.4.1 Village Selection Data

The village selection procedure involves a comparative benefit-cost analyses of a large number of village/settlements to select the most attractive ones that can be electrified under the available investment budget. This process, described in detail in Chapter 4, begins with the task of allocating the national RE budget to the provinces and then to the districts. Subsequently, benefit-cost analysis is used to select specific villages. This section outlines the data used in this procedure in the illustrative cases used in this study.

Economic and Financial Parameters

The major economic and financial parameters used are:

-	discount rates:	financial - 15 percent economic - 10 percent
-	planning horizon:	20 years
-	conversion factors: (shadow prices)	foreign exchange - 1.0 unskilled labor - 0.9 RE equipment - 0.7

The discount rates are based on planning parameters used in other project appraisals, such as for the ADB (Ref 89). Some sensitivity analysis was done using an economic rate of 5 percent based on the work by Markandya (Ref 11). The planning horizon used also parallels other appraisals and is long enough to capture the most important benefit and cost streams since the present values of amounts beyond 20 years at these discount rates are relatively small.

The shadow prices were based on Markandya (Ref 11) as well as personal communications with the World Bank. The most important factor is the shadow price or conversion factor for RE equipment as this factor was used to convert financial or market prices for all RE inputs into economic prices. This factor of 0.7 is based on rounded values from (1) Markandya's shadow prices of 0.69 for electrical machinery and 0.68 for other large scale manufacturing and (2) the conversion factor of 0.65 implicit in the Rural Electrification District Master Plans.

Benefit and Demand Estimates

These are used to estimate the total potential economic and financial benefits of electrifying a village in the area exercise described in Chapter 4 where the villages are selected within a limited budget. This village estimation is based on coefficients which portray representative unit benefits in rupees per year, electricity use in kwh per year, and peak demand in kw (along with a peak coincidence or diversity factor) for each type of customer (see the table of parameters in Chapter 4, Table 4.6-1). The electricity use and peak are needed for the costing of the RE system. The customer types considered at this point are: households, irrigation tubewells, rural industries, and commercial establishments. Illustrative analyses of these customer types were performed as described in Appendices D, E, and F which were based on the data available within the schedule and resources of this study. The benefit estimates are based on willingness-to-pay analysis using cost savings and consumer surplus approaches based on the following types of data described in the Appendices:

- Tubewells - basic approach is the cost savings between electric and high and low speed diesel pumpsets; see Appendix E (the operating costs and levels, efficiency levels and energy prices need refinement).

  - o capital costs for diesel engines, electric motors, and pumps based on communications with manufacturers and suppliers.

  - o operating levels or annual hours of operation were based on the District Master Plans, other reports (e.g., Ref 119, 49, 26, 131, 126, 133, 156, 177-179), meetings with agriculturalists and agricultural engineers and professionals, and examination of agricultural practices.

  - o operating and maintenance costs based on case studies from District Master Plans for Electrification (e.g. Refs 148, 150, 160, 161 and others) and tubewell studies (Ref 17).

  - o energy, pump and discharge efficiency levels from ENERCON agricultural sector work (Ref 140); in the future these data can be refined based on current ENERCON work.

  - o fuel prices based on team estimated rural market and economic prices

- Rural Industry - basic approach is the cost savings between electric motors and high speed diesel engines (see Appendix F).

  - o same data sources as used for irrigation tubewells.

- Household and Commercial - basic approaches are (i) cost savings from kerosene lighting and (ii) consumer surplus based on estimations of current use and payment levels; see Appendices C and D (much of the basic data needs confirmation from survey work which also examines income level and regional variations).

  - o kerosene use levels and prices are based on team estimates (see Appendix C) using household expenditure data (Ref 130, 141), international data (Ref 88), and study team kerosene lantern use tests as previous estimates for RE analyses were inconsistent with national use figures.

  - o basic electric lighting levels are team estimates.

  - o electricity use for additional lighting, fans and other appliances are based on the RE District Master Plans, pretest results from team survey, team estimates.

  - o willingness-to-pay based on existing tariff and initial connection, wiring and other costs and not on any actual survey work (team survey results will be available in July).

Given the importance of the above data estimates and the lack of a large body of consistent data, ongoing work revising these analyses is clearly needed. A program for this revision is also presented in this chapter.

The unit customer coefficients developed on the basis of the above data are applied to the total number of customers of each type in the village. Because of the approximate nature of the basic data that is currently available, various types of detail (see below) are not judged to be worthwhile and are not varied or included in the analysis. When the databases improve, such details can be considered. Some of these details are: projected customer growth rates, annual use increases for connected customers, regional and local variations, and income level distinctions. Furthermore, once information on the complementary investment nature of RE is analyzed, a basis for capturing the future growth catalyzed by RE in a setting of other investments and conditions may be established. In addition, estimates of customer penetration rates do not need to be incorporated into the analysis because the recommended customer connection policy is to require very high penetration levels.

RE Electricity Cost Estimates

The cost side of RE involves estimating the following components: customer connection, village distribution (LT and HT lines and transformers within the village), and area distribution (HT lines and substations connecting villages with the grid). As presented in Chapter 4, average unit costs were developed.

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For example, the connection costs used are Rs 1,200 for households and commercial establishments, Rs 9,000 for rural industry, and about Rs 40,000 for tubewells. For the village distribution, an average cost of Rs 2,500/kw demand at the village level assuming a village coincidence or diversity factor of 0.85 was used. For the area distribution, unit line costs per kilometer were estimated based on market costs. All of these costs were based on current financial equipment prices and construction costs under current technical standards and design approaches. These prices, costs, standards and approaches will change, and consequently new unit cost figures will need to be continually developed.

The equipment, materials and labor required to create the total and average costs estimates are based on revising and updating the work done in several past District Master Plans for electrification.

The bases for the RE cost reductions are described in section 5.4.3.

In the village selection procedure, only the RE costs are used. The generation and transmission costs are not included in order to simplify the procedure for ease of use. The exclusion of G&T costs has one drawback in that the differences in these costs due to different load factors is not captured. Given the lack of detailed information on this subject, it is judged that the ease of application gained is more important. On the other hand, it is important to note that G&T costs are included in the work on tariffs.

Village Geography and Demography

On the RE cost side, besides the unit costs, the other major input to the costing of RE area distribution in the area exercise is the specific spatial location of each village. This location is not simply a distance from the grid but the physical location relative to other villages as well. This will clearly require detailed maps of all rural areas. For the case studies, such maps were available from the District Master Plan work done for WAPDA (e.g. Ref 160 and 151).

On the RE benefits side, the total benefits estimations are based on the number of total potential customers for each type. Therefore, for each village in the case study in Chapter 4, data on the number of customers are based on the District Master Plan and when needed, estimations by the study team of the relationships between population and the other customer types based on the master plans.

National to District Investment Budget Allocation Basis

To determine the RE investment budgets on a district level, the illustrative allocation procedures described in Chapter 4 use a number of alternative parameters whose accuracy and availability will require further work. The candidate parameters for the allocation of the national budget to the provinces are: population, rural population, non-electrified rural population, non-electrified villages and/or settlements, and low income

population. The sources for these data are the RE program reports and various census reports. For the allocation of the provincial budget to the districts, a combination of a population based parameter and a development level index is suggested, and the procedure needs to be developed with policy makers. The source for a illustrative development index is the work of Pasha and Hasan (Ref 45) which is partially presented in Appendix I.

Intensification

The selection of villages for intensification of electrical connection or "backfill" requires a database of the current level of electrification in all villages. In this study it is suggested that, for the next three years (and then to be revised), 50% of the RE investment budget be allocated to intensification because of its cost-effectiveness and equity as discussed in Chapter 3. The selection criteria for these villages is the same as for new villages as described in Chapter 4. Therefore, the data bases and needs are the same as those outlined above. The major difference is that the number of potential customers is based on the number of those that are still unelectrified rather than the total village population of households and other customer types.

As-Built Distribution Maps

For the case study in each province, the maps for the as-built distribution systems were taken from the existing RE District Master Plans.

Least Cost Distribution Expansion Plans

For each provincial case study, a least cost distribution expansion plan was developed by the study team. This plan took into account the transmission line configuration, locations of grid stations, choice of primary voltage and phase options, optimal equipment, sizes, and other cost saving measures. Alternative network configurations were studied and the least cost configuration was adjusted on the basis of voltage drop studies, costs of capital investment, and technical losses. The conductor selection for the primary system was optimized by minimizing cost of capital and energy losses to meet the required voltage quality.

6.4.2 Tariffs and Subsidies

Willingness-to-Pay (WTP) and Ability-to-Pay (ATP) Estimates

WTP estimates are used to consider possible tariff changes while ATP estimates are needed to understand the possible reactions. The WTP estimates are the gross benefit estimates discussed above in section 6.4.1 and used in the analysis presented in Chapter 3. To support the recommendation to move towards full recovery of rural electricity

supply costs, the ATP is used. For rural industry, commercial and irrigation tubewell customers, their financial WTP estimates are used to indicate their ATP. For the households, the ATP is based on the 1984-85 household expenditure survey (Ref 141) and the percentages of income spent on energy and discretionary expenditures.

Tariffs

The current tariffs are based on the July 1987 WAPDA Schedule of Tariffs (Ref 154) and the historical record of the fuel adjustment surcharge (FAS) in the WAPDA Power Statistics (Ref 57) Appendix XVII. For this study an average FAS for 1987 of about 0.22 Rs/kwh was used.

Demand Patterns

The demand patterns necessary to estimate the electricity supply costs of serving different customers and consequently the appropriate tariffs in this study are: kwh/year, peak kw demand, annual load factor (based on the kwh/year and the peak kw), and peak coincidence or diversity factor. Each of these factors was developed in Appendices D through G for the analyses presented in Chapter 3 using the data described in the village selection section above. Table 4.6-1 in Chapter 4 presents the gross benefit values used, and these estimates integrate much of the data on demand patterns presented in the customer-related appendices.

The supply costs are very sensitive to these factors and consequently need refinement and continual monitoring. Although not covered in this study, it will be useful to understand the degree to which different customers' demands can be managed so that interruptible tariffs can be designed.

Financial and Economic Costs of Total Electricity Supply

The total system costs are used to estimate how much to charge customers based on how much it costs the utility to serve them. In addition, these costs are used to estimate the utility's need for any transfer payments from Government and whether the utility and/or Government is subsidizing/taxing some customer types.

These data are the same as those described under section 6.4.1 above with the major addition of including the generation and transmission (G&T) costs. The estimation of financial and economic G&T costs is described in Appendix B and summarized in Section 3.2. The study team made its own analysis as current estimates were not available. G&T costs were estimated to be: (i) a capacity or fixed charge (economic - 30,000 Rs/kw-delivered and financial - 5,200 Rs/kw-delivered) and (ii) an energy or recurrent charge (economic -

0.61 Rs/kwh-delivered and financial - 0.245 Rs/kwh-delivered). The financial estimates are based on the WAPDA Power System Statistics (Ref 57), and the economic estimates are based on the UNDP/World Bank Power System Planning exercise (Ref 175). Since G&T costs form a very large percentage of total electricity costs, it requires more detailed analysis than was feasible in this study.

6.4.3. Technical Specification, Design Parameters, and Cost Reductions

Current RE technical specifications, design parameters used in developing the basic RE costs estimates are based on current WAPDA regulations. The information sources used are: WAPDA price bulletin, latest WAPDA purchase orders, WAPDA Power Statistics, prevailing market prices, WAPDA technical specifications for 11 kv, 33 kv, and 0.4 kv lines, WAPDA design criteria for distribution lines.

The bases for developing the suggested alternative specifications, parameters, and costs are: data from other countries both developing and developed, market prices for alternative equipment, new engineering design work specially undertaken for this study, and extensive costing of alternative system designs. Appendices T1 through T6 along with the supporting studies present the data used in this work. It is important to note that the more important basic inputs to the technical design work are not the equipment information but the development of numerous alternative system configurations enclosed in these Appendices which were subjected to technical and cost analysis. The data from other countries were largely from the ADB Regional RE Survey (Ref 25), personal communications, and team experience.

Overall, the data bases for this study were numerous and disparate as there was not unified and complete ones available on RE. The data collection effort included meetings with many WAPDA and AEB officials, federal and provincial government staff (such as the Energy Wing of the Ministry of Planning and Development and the Punjab Department of Planning), USAID and PTAT staff, and World Bank staff. See Appendix A for a list of personnel met. Furthermore, an extensive library was collected and reviewed for this study; see the Bibliography. This collection includes a wide range of GOP, WAPDA, USAID and other agency reports on Pakistan as well as significant coverage of RE in other developing countries.

6.5 Summary

The long-term objective for WAPDA will be the establishment of an integrated data base. A crucial component of this data base will be a comprehensive village/settlement data base. To this end, basic data need to be collected for all of the villages/settlements in Pakistan. Many of these data are already available in computerized format and

need only to be adapted to RE planning use. Other data must be collected using surveys, maps, and secondary data sources.

An extensive list is included in this Chapter on the required studies, preparatory work, and data base development activities that are required over the next twelve months. They are listed by priority (within the first 3-4 months of the plan; within the first 5-7 months; and within the first year) and include:

- Project implementation strategies and preparatory work, in order to begin the plan;

- Technical and cost manual preparation;

- Area planning design and selection procedure, including the preparation of a preliminary area planning and village selection manual;

- Development of village specific rural electrification expansion plans for 750 villages immediately and 5000 villages during the first year of the plan';

- Collection of geographic and demographic village/settlement information, including the mapping of all grid stations, feeders, and settlements/villages.

- Implementation of extensive benefits and tariff studies; and

- Studies of the technical equipment options that were discussed in Chapter 5.

Chapter 7

Implementation Strategy

7.1 A Perspective on the Implementation Strategy

The implementation strategy outlined in this Chapter is designed to:

(i) Provide a fast-start to the program;

(ii) Ensure the commitment and participation of the newly appointed managers at an early stage and to familiarize them with the special requirements of rural electrification;

(iii) Have the new organization and advisors in place at an early stage and ensure that a strong vigorous initial thrust is provided.

(iv) Have the new style RE program fully operational by 1990.

The present target date for completion of the review and approval of the Master Plan is by the end of July 1988 and thus the implementation date is deemed to be starting from August 1st.

The various proposals outlined in this report when aggregated represent a major step-change in the policies, attitudes and organization structures for RE, particularly in WAPDA the executing agency and also in the Government of Pakistan. This change must be considered in the reality of the present situation in WAPDA and in the context of:

1. the ongoing construction, operation, maintenance and administrative programs of the total system;

2. the generation and transmission expansion programs; and,

3. the USAID-WAPDA Distribution Improvement Program.

The capacity of WAPDA to absorb and implement a further program of this magnitude (as presented in the earlier chapters) must be carefully considered and an implementation strategy developed which will ensure that the program is effectively carried out. As outlined in Chapter 2 it is thought that considerable external assistance, both Pakistani and expatriate, will be required to support the new organization at the beginning and eventually to ensure it will have the indigenous capacity to continue to implement and improve the new arrangements.

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7.2 The Logical Sequence

There is a logical sequence of steps which should be taken to ensure the orderly development of the total change program; within this framework priorities can be established. These priorities can arise due to the necessity of immediate action to be taken on specific activities and/or where interim or transitional studies or activities should be undertaken in order to provide an impetus and driving force to the overall change program.

There is also the necessity to avoid a period of relative inaction during which the various elements are being put in place and overlap with the existing systems. It would be desirable that the main proposals be implemented (on a preliminary basis) on a portion of the RE budget for 1988-89. The preliminary guidelines and procedures could be developed within two to three months and would be available in time to be used as the basis for executing part of the second half of the FY 1989 Government financed RE program, perhaps 50 percent of the second half (or 25 percent of the full year program). If 6000 villages were to be electrified, this would involve approximately 750 villages to be electrified and intensification/backfill in at least another 750 already electrified villages. In addition, the preliminary guidelines should be the only basis for executing any and all externally financed RE programs.

The short-term implementation program may be summarized as follows:

1. By October, 1988: Approval of new REO positions and appointment of new personnel.

2. By Beginning 1989: Completion of RE intensification program development, preliminary area planning manual for RE expansion, and preliminary technical instruction manual.

3. By the End of March, 1989: Selection and work plan for the electrification of new villages, and the development and implementation of a work order procedure for selected projects. Also, arrangements for overseas training and procurement of expatriate advisors should be complete.

For the other portion of the Government financed RE program, the selection procedures, costing and planning approaches used during the period prior to the accelerated program would continue to be used. Thus until the interim guidelines are extended to applications throughout the system, the Province specific selection procedures will be used (by the Provinces and WAPDA) for the major portion of the Government financed program. This portion would be 75 percent in the first year and rapidly declining in subsequent years as indicated in the discussion herein.

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The prior procedures were discussed in some detail in the initiation report for this Master Plan (Ref 30). These prior village/settlement selection criteria are Province specific, but all involve population (or numbers of households) and distance to the grid and in some cases maximum distance criteria are set. Continued use of these criteria for a portion of the Government financed RE program would be a transition phase. Early in this transition phase (and prior to any training in the new procedures or the availability of the preliminary guidelines) efforts should be made to familiarize key Provincial and AEB staff with the concepts of the new approach. This could be accomplished by disseminating sections of this report, in particular Chapter 4 which gives an example of the procedure application, to these key staff. Their consideration of the example can heighten their awareness of the importance of considering relative location in defining area distribution options and may influence their choice of technical options for electrifying villages selected under existing population and distance criteria. Also the distribution of this material may begin the process of familiarizing these staff with the principles of selection based on economic ranking. Such transition efforts will help the longer term implementation of the program.

There are four main stages in the implementation process:

A. The priority work as outlined above and in Section 6.3 to apply the new procedures and guidelines to approximately 25 percent of the Government financed (and 100 percent of the externally financed) in the 1989 RE budget.

B. The installation of the new organization structures and the appointment and induction of the new managers.

C. The initial stages of the design and implementation of the new systems and procedures including staff communication and training programs.

D. The consolidation of the new organization and new systems into the ongoing work in the distribution function.

In the early stages external assistance will be necessary to:

i. develop the preliminary guidelines and procedures on the technical design parameters, the economic parameters and the area planning and village selection criteria; and,
ii. to assist WAPDA at the field division level to nominate areas for village/settlement survey, canvass, design costing and final selection.

7.3 Implementation Steps

The following steps are necessary to initiate the program:

(1) WAPDA to obtain GOP approval for the new senior positions, as outlined in section 2.4.

(2) WAPDA to appoint the six senior managers for the new Rural Electrification Office (REO).

(3) A preliminary program is prepared for backfill/intensification in 750 existing electrified villages.

(4) A preliminary area planning manual is developed to enable WAPDA and the Provinces to prepare projects for 750 new villages to be electrified under Government financing, and other villages to be electrified under USAID financing in the current year.

(5) A preliminary technical instruction manual is prepared for the "New" rural network configuration detailed in Chapter 5.

(6) The new villages are designed and costed, and cost/benefit indices prepared based on the preliminary criteria developed in 4 and 5 above. This activity will involve both WAPDA and the Provinces.

(7) A work plan is then prepared for the specific program of electrifying the villages selected on this new basis by the provinces.

(8) Preliminary work order, project supervision and control arrangements compatible with those designed by the PTAT team are developed and implemented for these selected projects.

(9) Terms of reference and requests for proposals are prepared for the procurement of expatriate advisors and local consultants (as needed) for the new REO.

(10) A training visit program is prepared for the new managers in REO to visit five to six selected utilities worldwide to examine the Rural Electrification facilities in different countries.

There are a number of other studies and preparatory work (outlined in Chapter 6) which are essential:

- to support the other major policy reforms needed- finance, tariff and connection policies etc.; and
- to modify the preliminary guidelines and manuals by the earliest possible date.

Steps 1 to 10 above should be undertaken in the first phase of the implementation program. A work plan (prepared by the new WAPDA managers and consultants) would be completed to cover the balance of the studies. This work plan for the studies should be prepared at the earliest date and this plan could allow some of the more critical studies to be done at the same time as the first phase work is being implemented.

In addition, it will be necessary to implement a follow on area planning program for 3000-5000 villages/settlements to have a sufficient number of well planned, designed and costed projects available for financing consideration by the various international funding agencies.

7.4 Implementation Schedule

A schedule of the implementation of the steps described above is

(i) Steps 1 (approval of new positions) and 2 (appointment of personnel) are to be completed by the end of October, 1988 with all new managers appointed.

(ii) Steps 3 (program for RE intensification), 4 (preliminary area planning manual for RE expansion) and 5 (preliminary instruction manual) should normally follow sequentially after 2 (appointment of personnel) but as outlined at the beginning of this chapter, it is considered desirable that these should also start in August or September and be implemented by a specially selected WAPDA Task-force working in conjunction with the consultants in order to have these three steps completed by the end December. This exercise could be done on a basis somewhat similar to the ADB financed RE project using multiple consultants but with uniform prescribed systems and procedures.

(iii) Steps 6 (selection of new villages) and 7 (work plan for electrification of new villages) would be done by the same team as above but within the new REO organization and with the full participation of the new management team. This work is to be completed by the end of January 1989.

(iv) Step 8 (work orders for selected projects) would be done in parallel with steps 6 and 7 above and would also be completed by the end of the first quarter of 1989.

(v) Steps 9 (procurement of expatriate advisors for the REO) and 10 (overseas training and visitation program) would be completed in parallel with steps 6-8 above and all these arrangements also finalized by the end of January 1989.

In order to achieve this 10 step program, consideration must be quickly given to the appointment of short term consultants so that this program can commence by the indicated date. Any slippage at this time can delay their program into the next financial year and also lose much of the impetus and urgency that has already been established.

To promote local equipment manufacture and to minimize delays in the implementation, the technical standards and designs should be developed and meetings with local industry should be held as soon as possible.

It would be anticipated that the in-house advisors would be on-site by 1st April 1989 and the first major task of the new organization and their advisors would be to develop a 21-month plan to cover the period until the end of December 1990, fully scheduled on 3-month time slots. This work plan would include:

(i) The ongoing planning and project management of the electrification program;

(ii) Preparing the detailed systems and operating procedures for all aspects of the rural electrification program; and,

(iii) Appointing, inducting and training the staff for the new organization.

This 21-month plan would cover the implementation and completion of all the studies listed in this report and the finalization of all systems, guidelines, standard operating procedures and instruction manuals. It will also include details of the training programs to familiarize staff on the operation of the new procedures.

7.5 Summary

The overall strategy outlined in this Chapter is designed to:

(1) Provide a fast-start to the program;

(2) Ensure the commitment and participation of the newly appointed managers at an early stage and to familiarize them with the special requirements of rural electrification;

(3) Have the new organization and advisors in place at an early stage and ensure that a vigorous initial thrust is provided; and,

(4) Have the new style RE program fully operational by 1990.

When aggregated into a total plan, the various proposals made represent changes in Government policy and WAPDA operations. The realities of the present work-load in WAPDA and its capacity to undertake and effectively implement this program must be considered.

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It is proposed that external assistance will be necessary to help the new REO and other WAPDA staff, comprised of short-term consultants which could be appointed immediately to develop and implement preliminary guidelines, procedures and instruction manuals to plan, design, select and construct rural projects in the "New" format. The short-term consultants will help to set up the new organization, work with the new managers and help them to prepare terms of reference for the recruitment of a team of advisors to work with them in hands-on counterpart roles.

The program requires an effective implementation strategy to ensure that the short-term priorities are addressed, that issues having a longer-term perspective are initiated and that the impetus already gained is not lost in a period of relative inaction. Arising from the detail of the studies and analysis outlined in the report it is now evident that an immediate program of implementation can be started based on preliminary manuals which can be quickly provided.

It is proposed that 25% of the 1988-89 budget for rural electrification should be earmarked for implementation under the new procedures. This program would comprise 750 new villages and intensification/backfill of at least 750 already electrified villages. Additionally it is considered that all projects proposed for funding by the international development agencies would be planned and designed using only the new procedures. There are four main stages in the implementation process:

A. The priority work as outlined above and in Section 6.3 to apply the new procedures and guidelines to approximately 25 percent of the Government financed (and 100 percent of the externally financed) 1989 RE budget.

B. The installation of new organization structures and the appointment and induction of the managers.

C. The initial stages of the design and implementation of new systems and procedures including staff communication and training programs.

D. The consolidation of the new organization and new systems into the ongoing work in the distribution function.

It is proposed that stages A-C can be started immediately and completed by the end of March 1989. Stage D would be planned for implementation in the period April 1989 to December 1990 and a detailed implementation plan for this phase will be prepared by the new REO manager in the period January 1989 to March 1989.

Bibliography

1. Andersen, Dennis and Ralph Turvey, Electricity Economics: Essays and Case Studies, World Bank Research Publication, 1977.

2. Briscoe, John, Willingness to Pay for Water in Rural Areas, for the World Bank Research Approval Committee, 1987.

2A. --Office Memorandum, Briscoe, John to Ljung, Per, "India: Study on Willingness to Pay for Rural Water: Back to Office Report", Aug.14, 1987.

2B. --Office Memorandum, Briscoe, John to Ljung, Per, "Zimbabwe, Willingness to Pay for Rural Water Study: Back to Office Report", Aug.31, 1987.

2C. --Office Memorandum, Briscoe, John to Ferranti, David de, "Pakistan: Sector Work and Willingness to Pay for Water Study: Back-to-Office Report", May 11, 1987.

3. Broadway, Robin W.and Wildasin, David E., Public Sector Economics (2nd ed.), 1984.

4. Cecelski, Elizabeth and Glatt, Sandra, The Role of Rural Electrification in Development (Energy in Developing Countries Series), 1982.

5. deLucia and Associates, Energy Use in Pakistan's Agricultural Sector. Prepared for Hagler, Bailly & Co. and the Government of Pakistan, 1986.

6. Doryan-Garron, Eduardo, A., Rogers, Peter and Umana, Alvaro, (report for USAID), Framework for the Analysis of Rural Electrification Projects, 1986.

7. United Nations (report), Guidelines for Project Evaluation, No. 2, 1972.

8. United Nations (report), Guide To Practical Project Appraisal: Social Benefit-Cost Analysis in Developing Countries, 1978.

9. A.D. Little, report to USAID/ Government of Pakistan Water and Power Development Authority), General Policies and Implementation Guidelines: Rural Electrification Program, Pakistan, 1983.

10. Irvin, George (with Richard Brown), Modern Cost-Benefit Methods: An Introduction to Financial, Economic and Social Appraisal of Development Projects, 1977.

11. Markandya, A., Parker, A., and Pearce, D. (report for the South Asia Energy Division), Shadow Prices in Pakistan, 1986.

12. Pyndyck, R., The Structure of the World Energy Demand, 1979.

13. Roemer, Michael and Stern, Joseph J., Cases in Economic Development: Projects, Policies and Strategies, 1981.

14. Sandersen, Kevin, Comparing Methods of Benefits in Rural Electrification, Costa Rica: The Puerto Viejo Case, John F. Kennedy School of Government, 1986.

15. Strumpel, B. et al (mimeo), Surveys of Consumers 1972-1973: Contributions to Behavioral Economics, 1975.

16. Webb, Michael and Pearce, David, Economic Benefits of Power Supply, September 1985.

17. Face Ltd., Zafar & Associates and Ace Ltd., Private Tubewell and Rural Electrification Project, Feasibility Report, D. G. Khan Canal Command Area (Punjab), Volume II, February 1985.

18. Stuhlmann, Allen H., and Finance Team EBASCO-AEPES-ITECO Joint Venture, Cost of Service and Rate Study, March 1986.

19. Boice, David G., End of Tour Report, May 7, 1986.

20. EBASCO/AEPES/ITECO Joint Venture, Single Phase Applications in Power Distributon, February 12, 1986.

21. Finance Team Water and Power Development Authority EBASCO-AEPES-ITECO Joint Venture, Willis William D., Shahab Ud Din, and Akhlaq Ahmed, Proposal For Tariff and Rate Design, May 1987.

22. Office of the Chief Engineer Design (Distribution) WAPDA, Primary Voltage Study, February 1987.

23. Seventh Five Year Plan Load Management Potential

24. Squire, Lyn, Little, I.M.D., Durdag, Mete, Development Economics Department, and Development Policy Staff, Application of Shadow Pricing to Country Economic Analysis with an Illustration from Pakistan, June 1979.

25. Smith, D. V., Mehta, D. B., and Hayes, P. J., Report of the Regional Rural Electrification Survey to the Asian Development Bank, October 1983.

26. Department of State Agency for International Development, Project Paper Pakistan - Rural Electrification 391-0473, September 1982.

27. Pakistan Water and Power Development Authority, Accelerated Rural Electrification Programme, Interim Report, January 1988.

28. Pacific and Asian Journal of Energy, Volume 1, Issue 1, January 1987.

29. Mathtech Incorporated, Enerplan Project Renewables Special Study, January 1988.

30. deLuc[illegible] and Associates, Initiation Work For Rural Electrification Master Plan Revision, Mathtech Inc, Energy Wing, Ministry of Planning and Development, Islamabad, Pakistan, February 1988.

31. Munasinghe, Mohan, Rural Electrification for Development - Policy Analysis an Applications, 1987.

32. Mathtech Incorporated, Energy Wing Speical Study Decentralized Power Generation Options Study (draft), February 1988.

33. Arthur D. Little, Inc., General Policies and Implementation Guidelines, Rural Electrification Program Pakistan, March, 1983.

34. Staub, William J. and Koppel, Bruce, "Monitoring and Evaluation of Benefits in Agriculture and Rural Development", Asia Development Review, Volume 4, n 1, 1986.

35. Khan, Mahmood Hasan, "Public Policy and Agricultural Transformation in Pakistan", The Pakistan Development Review, Vol. XXV, Nos. 3 & 4, 1985, pp.305-329.

36. Kazi, Shahnaz and Sathar, Zeba, "Differences in Household Characteristics by Income Distribution in Pakistan", The Pakistan Development Review, Vol. XXIV, Nos. 3 & 4, 1985, pp. 657-667.

37. Aftab, Khalid and Rahim, Eric, "The Tubewell Industry in Pakistan Punjab: Entry, Survival and Role of Small-Scale Engineering Units", Economic Bulletin for Asia and The Pacific, Vol. XXXVI., No 1, June 1985.

38. Sahibzada, Shamim and Mahmood, Mir Annice, "The Project Monitoring System in Pakistan: An Evaluation", The Pakistan Development Review, Vol. XXIII, Nos. 2 & 3, 1984, pp. 165-174.

39. Qureshi, Sarfraz K., "Comments on 'The Project Monitoring System in Pakistan: An Evaluation'", The Pakistan Development Review, Vol. XXIII, Nos. 2 & 3, 1984, pp.175-178.

40. Mehdi, Istaqbal, "Performance Evaluation of Public Enterprise in Pakistan: Experiment in Social Accounting System", The Pakistan Development Review, Vol. XXIII, Nos. 2 & 3, 1984, pp. 179-203.

41. Mahmood, Zafar, "Income Inequality in Pakistan: An analysis of Existing Evidence", The Pakistan Development Review, Vol. XXIII, Nos. 2 & 3, 1984, pp. 365-379.

42. Qureshi, Sarfra, Abbas, Kalbe, Siddiqui, Ahmed Naeem and Ghani, Ejaz, "Rural Credit and Rural Development: Some Issues", The Pakistan Development Review, Vol. XXIII, Nos. 2 & 3, 1984, pp. 273-282.

43. Arif, Muhammad, Ahmed, Bashir and Jannisar, Muhammad, "Income, Assets and Poverty", Expansion of Employment and Income Through Local Resource Mobilisation: A Study of Three Villages in Pakistan, pp.27-57, (ARTEP), Bankok, 1984.

44. Arif, Muhammad, Ahmed, Bashir and Jannisar, Muhammad, "Employment and Production Potential", Expansion of Employment and Income Through Local Resource Mobilisation: A Study of Three Villages in Pakistan, pp.88-117, (ARTEP), Bankok, 1984.

45. Pasha, Hafiz and Hasan, Tariq, "Development Ranking of Districts of Pakistan", Pakistan Journal of Applied Economics, Vol. I, No. 2, pp. 157-192, 1982.

46. Gotsch, Carl and Brown, Gilbert, and World Bank, "Growth and Structural Change in Pakistan Agriulture: 1960-1975", Prices, Taxes and Subsidies in Pakistan Agricultre, 1960-1976, WP No. 387, pp. 7-32, April, 1980.

47. Helbock, Richard, "Urban Population Growth in Pakistan", The Pakistan Development Review, Vol. XIV, No. 3, pp.315-333, Autumn, 1975.

48. Afzal, Mohammad, The Population of Pakistan, pp.53-75.

49. Department of Agriculture Government of The Punjab, Punjab Agricultural Statistics, 1976-1977.

50. Rhee, Seung Yoon, "Energy Demand Management of Pakistan", pp. 39-53, April, 1985.

51. Deverick, Barbara, Gellerson, Mark, Stovall, John and Shelton, Robert, Rural Electrification in Bangladesh: Management, Engineering, and Financial Assessment, (ORNL/TM-10042).

52. Rashid, Javed, "Village Electrification - An Assessment", Daily Nation, pp.1-2, Nov., 23, 1987.

53. International Consulting Engineers and Water and Power Development Authority, "Detailed Feasibility Study for Rural Electrification in Nowshera Virkan Area", Vol. I, Feb.14, 1978.

54. Gellerson, Mark, "Sri Lanka Rural Electrification Assessment", October, 1987

55. Barnes, Douglas F. and Jechoutek, Karl, "Rural Electrification Issues: Growth, Options, and Impact (With a Case Study in India), March 8, 1985.

56. Water and Power Development Authority and Rural Electrification Organization, "Working Paper on Accelerated Rural Electrification Programme For Implementation of Prime Minister's Directive to Achieve 90% Village Electrification in Four Years (1986-1990), Feb. 25, 1986.

BIBLIOGRAPHY 4

57. Water and Power Development Authority and Planning Department Power Wing, "Power System Statistics Twelfth Issue", October ,1987.

58. IED Consultants SA, "Interim Report on The Sixth Plan 1983-1988" December, 1982.

59. Markandya, A., "The Price Impacts of Changing Energy Prices in Pakistan", (MLEC), October, 1987.

60. Asian Development Bank and Development Policy Office, "Study of The Bank's Operational Priorities and Plans For The 1980's", June, 1982.

61. The World Bank, "Staff Appraisal Report Bangladesh, Power Transmission and Distribution Project", December 10, 1985.

62. Government of Pakistan, Energy Resources Cell, Ministry of Petroleum and Natural Resources, "Energy Data Book", 1978.

63. Pakistan, "Load Management Potential Seventh Five Year Plan" (earlier draft of Ref. 23?).

64. "Decentralised Power Generation Options Special Study", January 31, 1988.

65. United States Government Memorandum, Bever, James to Jusain, Raza Syed, "Applicability of ADB's Rural Electrification Project, Loan 561 PAK(SF) for USAID's R.E. System Expansion/Master Plan Special Study", November 8, 1987.

66. Wasay, Abdul, "An Urban Poverty Line Estimate", The Pakistan Development Review.

67. Naseem, S.M., "Mass Poverty in Pakistan:Some Preliminary Findings", The Pakistan Development Review.

68. Alauddin, Talat, "Mass Poverty in Pakistan : A Further Study", The Pakistan Development Review

69. Gellerson, Mark W., "The Economics of Rural Electrification Projects: Theory and Case Study of Pakistan", The Pakistan Development Review, Vol. XXI, No. 3, (Autumn), 1982.

70. Richardson, Harry W., "The Costs of Urbanization: A Four-Country Comparison", Economic Development and Cultural Change, 1987.

70b. Qutub, S.A., Richardson, H.W., "The Costs of Urbanization: A Case Study of Pakistan," Environment and Planning, vol 18, 1986, pp. 1089-1113.

71. Water and Power Development Authority and Planning Department Power Wing, " Power System Statistics Twelfth Issue", October, 1987.

72. Water and Power Development Authority, " Proforma PC-1 Rural Electrification 1988-93", November, 1987.

73. Data Collection Sheets for House Hold Sampling, "Socio-economic Survey of Rural Electrification", Sri Lanka, 1986-87.

74. Mubayi, Vinod and Lee, John, " A Preliminary Analysis of Energy Supply and Consumption in Pakistan", 1973.

75. Department of State Agency for International Development, "Project Paper Bangladesh, Rural Electrification III", June, 1986.

76. V.N. Kothari, Baroda, "End Notes India, Gujarti Study, Dept of Economics, Maharaja Savajirao University ", Volume 5, 1977.

77. Centre for Monitoring Indian Economy, "Current Energy Scene in India, Verbatim Extracts Mainly From Recent Official Documents", May, 1984.

78. Bhatia, Ramesh, "Economic and Social Commission For Asia and The Pacific", April 26, 1984.

79. Agency for International Development, "The Philippines: Rural Electrification", Report No. 15, December, 1980.

80. National Electrification Administration, "Status of Program Implementation", December 31, 1985.

81. National Electrification Administration and Rural Electrification cooperatives, "Financial Organization and Technical Assessment", 1986.

82. Memo: Impact of Tractorization on Farm Production and Farm Employment, List of Guest Participants in the Discussion to be held at PEARL INTERCONTINENTAL ON 23.8.1986.

83. Pakistan Misc. Agricultural Census Data.

84. World Bank Energy Department, "Power System Load Management Technologies", Paper No. 11, November, 1983.

85. World Bank Energy Department, " Economic Benefits of Power Supply", Paper No. 25, September, 1985.

86. U.S. Agency for International Development, "Willingness To Pay For Water In Rural Areas: Methodological Approaches And An Application In Haiti, Wash Field Report", No. 213, September, 1987.

87. Gellerson, Mark W., "The Economics of Rural Electrification Projects: Theory and Case Study of Pakistan", The Pakistan Development Review, Vol. XXI, No. 3 (Autumn), 1982.

BIBLIOGRAPHY 6

88 Leach, Gerald and Gowen, Marcia, "Household Energy Handbook, An Interim Guide and Reference Manual", World Bank Technical Paper Number 67.

89. Asian Development Bank, "Appraisal of The Rural Electrification Sector Project in Pakistan", Report No. Pak: Ap-39, November, 1981.

90. Power Distribution Wing and Water and Power Development Authority, "A Review of The Institutional Improvement Plan Power Distribution", May 1987.

91a. Power Distribution Wing and Water and Power Development Authority, "Model Divisions Reorganization Plan Instututional Improvement Program", Volume 1 of 2, Final Report, November 23, 1986.

91b. Power Distribution Wing and Water and Power Development Authority, "Annex To The Model Divisions Reorganization Plan Institutional Improvement Program", Volume 2 of 2, Final Report, November 23, 1986.

92. World Bank, "Pakistan Sixth Plan Progress and Future Prospects", Report No. 6533-Pak, February 26, 1987.

93. World Bank, "Staff Appraisal Report, Thailand, Provincial Power Distribution Project", Report No. 4201, May 17, 1983.

94. World Bank, "Thailand: Appraisal of the Accelerated Rural Electrification Project", Report No. 1467a-TH, February 1, 1978.

95. Asnworth J., et al, Office of Energy and Environment, USAID, Midterm Evaluation of The Pakistan Rural Electrification Project, Islamabad, Pakistan, August 22, 1986.

96. Dunnion, G, Water and Power Development Authority, Pakistan, Organization Study, WAPDA Power Wing, report to World Bank, September 1987.

97. D. Barnes, Electric Power for Rural Growth, How Electricity Affects Rural Life in Developing Countries, Westview Press, 1988.

98. World Bank, Staff Appraisal Report, Lao People's Democratic Republic, Southern Provinces Electrification Project, Report 6733-LA, May 18 1987.

99. Coopers and Lybrand Associates, Bangladesh Power Sector Tariff Study, Final Report, Executive Summary, August 1986.

100. Coopers and Lybrand Associates, Bangladesh Power Sector Tariff Study, Draft Final Report, August 1986.

101. World Bank, Staff Appraisal Report, Malaysia, Rural Electrification Project, Report 3733-MA, April 26, 1982.

102. National Rural Electric Cooperative Association et al, Productive Uses of Electricity in Rural Areas, Workshop Proceedings, Dhaka, November 15-19, 1982.

103. A. Stuhlmann, Institutional Improvement Program Cost of Service and Rate Study, WAPDA/USAID Distribution Program, draft report, March 1986.

104a. C. Moseley, "Institutional Reform and Modernization of WAPDA," memorandum, USAID, February 24, 1987.

104b. C. Moseley, "Institutional Improvement in WAPDA," memorandum, December 8, 1986.

105. World Bank, Thailand, Staff Appraisal Report, Provincial Electricity Authority, Second Accelerated Rural Electrification Project, Report 2875-TH, May 15, 1980.

106. World Bank, Indonesia, Rural Electrification Review, report 6144-IND, November 15, 1986.

107. World Bank, Bangladesh, Power System Efficiency Study, Activity Completion Report 031/85, February 1985.

108. World Bank, Malaysia, State of Sabah, Power System Efficiency Study, Activity Completion Report 068/87, March 1987.

109. World Bank, Staff Appraisal Report, Pakistan, Kot Addu Combined Cycle Power Project, Report 6020-PAK, April 28, 1986.

110. World Bank, Malaysia, Power Sector Issues and Options, report 6466-MA, April 30, 1987.

111. World Bank, Project Performance Audit Report, India: First and Second Rural Electrification Projects (Credits 572-IN and 911-IN), draft, March 11, 1986.

112. WAPDA, Comprehensive Power Distribution Training Program of the Power Distribution Program, May 1985.

113. WAPDA-USAID, "WAPDA/USAID Power Distribution Program Contract #391-0473 Monthly Report," June 15, 1987.

114. WAPDA-USAID, "WAPDA/USAID Power Distribution Program Contract #391-0473 Monthly Report," January 19, 1988.

115. WAPDA, Institutional Improvement Plan, June 30, 1987.

116. WAPDA, Reorganization Plan for the Area Electricity Boards and Circles, Institutional Improvement Program, June 30, 1987.

117. Hanemann, Michael, "Welfare Evaluations in Contingent Valuation Experiments With Discrete Responses," American Agriculture Economics Association, August 1984. [was in as 95--change number on report.]

118. Brodman, J, Rural Electrification and the Commercial Sector in Indonesia, Resources for the Future report D-73L, September 1982. [was in as 96--change number on report.]

119. Patel, S.M, Gupta R.K, Study on Conservation of Light Diesel Oil Used in Pump-Sets for Lift Irrigation in Gujarat State," Institute of Cooperative Management, January 1979.

120. USAID, "Amendment Program Assistance Approval Document, Pakistan Agricultural Commodities and Equipment," document 391-0468, May 1984.

121. Rural Electrification Corporation, Regional Rural Electrification Survey (India) Objectives, Approaches, and Institutional Aspects, volume 1, report to Asian Development Bank, New Delhi, August 1983.

122. Asaduzzaman, M., Chowdhury, O.H, Rural Electrification in Bangladesh (A Report For the Regional Rural Electrification Survey Sponsored by the Asian Development Bank, Bangladesh Institute of Development Studies, Dhaka, August 1983.

123. Institute of Philippine Culture, The Philippine Rural Electrification Program, report to Asian Development Bank Regional Rural Electrification Survey, Manila, September 1983.

124. Bowman, K, Rural Electrification in Papua New Guinea, report to Asian Development Bank, Australian National University, Canberra, July 1983.

125. Hagler, Bailly and C, A.D. Little, Private Sector Power Generation in Pakistan, Potential, Impediments, and Policy Issues, draft report to USAID, Washington DC, December 12, 1985.

126. Barnes, D.F, "Impact of Rural Electrification and Infrastructure on Agricultural Changes," Economic and Political Weekly, volume 21, no 1, January 4, 1986, pp. 26-34.

127. no reference

128. World Bank, Pakistan, Sixth Plan Progress and Future Prospects, Report 6533-PAK, February 26, 1987.

129. AFTAB Associates, A Study of the Residential Fuel Use Pattern in Pakistan, Report to ORNL and USAID, Islamabad, October 31, 1987.

130. G. Leach, Household Fuel Use in Pakistan, (draft) Mathech report to Energy Wing, Ministry of Planning and Development, Islamabad, June 1987.

131. PG and E, Water Pumping Load Management information.

132. deLucia and Associates, Draft, Report for Pakistan Power Distribution Project RFP, March 1988.

133. Harris, B., "Rural Electrification and the Diffusion of Electric Water-Lifting Technology in North Arcot District, India," B.H. Farmer ed, Green Revolution, MacMillan, 1977.

134. Economic Adviser's Wing, Ministry of Finance, 1986-87 Economic Survey, Government of Pakistan, Islamabad.

135. referemce as 134, but different extract.

136. World Bank Energy Department, Energy Efficiency: Optimization of Electric Power Distribution System Losses, Paper no 6, July 1982.

137. Mishra, S.N., Beljer, J., Cost-Benefit Analysis: A Case Study of the Ratnagiri Fisheries Project, Institute of Economic Growth, Delhi, 1976.

138. World Bank, Costs and Benefits of Rural Electrification, A Study of El Salvador, P.U. Report RES 5, Washington DC, 1975.

139. deLucia R., and Lesser M., Bangladesh: Preinvestment Evaluation of Small Scale Uses of Natural Gas, Joint UNDP/World Bank Energy Sector Management Assistance Program, April 1986.

140. Enercon, Energy Use in Pakistan's Agricultural Sector: An Initial Analysis and Proposed TEM Program, Islamabad, November 1986.

141. Federal Bureau of Statistics, Household Income and Expenditure Survey, 1984-85, Statistics Division, Government of Pakistan, Karachi, FBS-192/1000, part one.

142. Federal Bureau of Statistics, Household Income and Expenditure Survey, 1984-85, Statistics Division, Government of Pakistan, Karachi, FBS-192/1000, part two.

143. World Bank, Diesel Plant Performance Study, World Bank Energy Department Paper no 21, May 1985.

144. Programme Evaluation Organization, Evaluation of Rural Electrification Programme, volume 1, PEO, Planning Commission, Government of India, New Delhi, 1982.

145. G. Irvin, Modern Cost Benefit Methods, no publication place or date given.

146. National Engineering Services (Pakistan) Limited, Rural Electrification Programme in Pakistan, Feasibility Report of Dera Ghazikhan Project Area, volume 1, 1978.

147. Rauf, M.A., Rural Electrification in Pakistan, A Socio-Economic Study, report to WAPDA, 1979.

148. FACE, Rural Electrification District Master Plan, Mianwali, report to WAPDA 1984.

149. EMAC Engineers Ltd., Master Planning for Rural Electrification in Pakistan, District Mardan, report to WAPDA, no date, post 1983.

150. FACE, Rural Electrification District Master Plan, Sahiwal, report to WAPDA 1984.

151. Noon Qayum and Co., Master Plan for Rural Electrification in Pakistan, Sind Province, Final Report District Badin, report to WAPDA, Karachi, no date, post mid-1983.

152. Nespak National Engineering Services, Master Plan for for Rural Electrifiction, District Malakand (NWFP), Lahore September 1984.

153. US Agency for International Development, Country Development Strategy Statement, FY 1983, FY 1993, Pakistan, Islamabad, April 11, 1987.

154. WAPDA, Schedule of Tariffs, Electricity Operation Branch, July 1987.

155. Nigar Ahmad, World Employment Program Research, Paper on Rural Employment Policy Research Program, Peasant Struggle in a Feudal Setting, Geneva July 1980.

156. Romesh S. and Natarajan, T.V., "Policy options in Rural Electrification in India," Pacific and Asian J. of Energy, 1987, pp.44-53.

157. World Bank, Staff Appraisal Report; Second Irrigation Systems Rehabilitation Project, March 8, 1988 (Report No. 6991-PAK).

158. World Bank, Staff Appraisal Report; Pakistan; Punjab and Sind Agricultural Extension and Adaptive Research Project - Phase II, (Extension IV), January 27, 1987 (Report No. 6300-PAK).

159. Rogers, Peter "Estimating the Benefits of Rural Electrification Projects". Proceeding of the International Association of Energy Economists Annual Meeting (Fall 1986).

160. NESPAK, Master Plan for Rural Electrification, District Hyderabad, (Sind), Lahore, Final Report Vol 1 of 2, September 1984.

161. FACE, Lahore, Rural Electrification, District Master Plan, Bahawalnagar.

162. PG&E Agricultural Services, Rebate Programs for Water Pumping Customers, PG&E's 1986.

163. Bureau of Stat. Planning and Dev Dept Govt of Sind, Survey of Human Rural Settlements of 500 and Above Persons, general facilities. 1986.

164. Bureau of Stat. Planning and Dev Dept Govt of Sind, Survey of Human Rural Settlements of 200-499 Persons, general facilities. 1987.

165. Population Census Organization Stat Division, GOP, 1981 District Census Report of Rawalpindi, District Census Report 44, Feb 1984.

166. WAPDA, Annex P of Master Plan for Power Distribution Rehabilitation Expansion, 1985-1983, February 1986.

167. Ministry of Water and Power, "Minutes of the Meeting of the Committee Constituted by ECNEC to Evaluate the Implementation of Rural Electrification Programme Held on 11-2-1983," Islamabad, February 23, 1988.

168. Ostmark H.E., "Variation in Fuel Consumptioon in Baseline Study Data," Forestry Planning and Development Project, GOP-USAID, April 19, 1988.

169. Revenue Officer, WAPDA Sialkot no II, "CP-41 Along with Proforma A.B.C. for 2/88," memo to Chairman AEB, WAPDA Gujranwala, 15-3-88.

170. Fikri, Z., "Electric Energy Conservation in Agriculture," ? pp. 51-64.

171. Directorate General of New and Renewable Energy Resources, Ministry of Petroleum and Natural Resources, Energy Yearbook, 1987, Islamabad.

172. Ditto, 1984.

173. Saunders John, Davis J. Michael, Moses C. Galen, and Ross James E, "Rural Electrification and Development: Social Impact in Costa Rica and Columbia." Westviel Press, Boulder CO., 1978.

174. Leach, G., Household Energy in South Asia, IIED, London May 1986.

175. UNDP and World Bank, Power System Planning Study for Pakistan, draft report, February 1987.

176. Foster Wheeler Energy Ltd., Petroleum Products Infrastructure Study, Final Report, Vol IV, September 1986.

177. Ghulam Yasin, Private Tubewells in the Punjab, The Punjab Board of Economic Inquiry, Lahore. - 1975.

178. ACE, Feasibility Report Vol II, SCARP Transition and Improvement Pilot Project, Part Two, Annex G, June 1985.

179. ACE, Feasibility Report Vol II, SCARP Transition and Improvement Pilot Project, Part One, Annex A to F, June 1985.

180. Document of the World Bank, Pakistan: Issues and Options in the Energy Sector, Energy Department, June 1985.

181. WAPDA, Power Dist. Improvement Program, Institutional Improvement Plan, June 30, 1987.

182. AID Project No. 391-0473, Project Grant Agreement between Pakistan vs. USA for Rural Electrification, Sept. 25, 1982 (Conformed copy) and First - Ninth Amendatory Agreement.

183. AID Loan No. 391-K-189, Project Loan Agreement, between Pakistan vs. USA for Rural Electrification, May 23, 1983. (Conformed copy) and First - Fifth Amendatory Agreement.

184. Michael H. Zador, prepared for Prof. Peter Rogers for Energy Sector Planning in Developing Countries, Photovoltaic Applications for Rural Electrification, A Study of the Puerto Plata Project, The Kennedy School of Government, Harvard University, May 3, 1988.

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APPENDIX A
MEETINGS BY RURAL ELECTRIFICATION STUDY TEAM

Appendix A *

Meetings by the Rural Electrification Study Team

A. COMMITTEE MEMBERS

Shanab-ud-Din, Chief Engineer (Distribution/ Planning, WAPDA, Convenor
Muhammad Ziauddin, Member AC,
Abdul Aziz Sheikh, Addl.Secy. (Power) I&P Dept., Sind
Abdul Jalil Moghal, Addl. Secy. P&D, Peshawar
Zaffar-ud-din Sheikh, Chief Engineer (Power), Irrigation and Power Department, Punjab
Asghar Ali, Chief Economist, P&D Dept. Quetta
Capt. Ali Zaman Khan, Deputy Engineering Advisor-Power, Ministry of Water & Power

B. COMMITTEE MEETING ATTENDEES

M. Yunis Marwat, Dir Tech AEB Peshawar
Noor Ahmed Menghal, D.D. (ED) AEB Quetta
Mahmood Mohyuddin Khan, Director Tech G/
Mohammad Arshad Chatha, SO(RE) I&P Department
Muhammad Saeed, A.D. CED
Riaz Ahmad, Dir. Planning Power
Muhammad Yunis Khan, Dir. Technical AEB Islamabad
Manzur Ahmed, Director (Tech) AEB Hyderabad
Atta-ur-Rehman Khan, Director Planning (Power) WAPDA
Muhammad Izhar-ul-Haq, G.M. Planning (Power) WAPDA
Abdul Latif, Exec. Eng. WAPDA Peshawar Rep., CAEB Peshawar
Iqbal Ahmed, Chief-Water & Power, P&D, NWFP
Haroon Rashid Toosy, CE, Irrigation & Power, Punjab
Farhan Sabih, Assistant Chief-Energy Wing
Muhammad Eshaq Khan, Director (Standards), WAPDA

C. WAPDA

1. M. Ayub Sadozai, Member Power
2. Wassem Khan, Managing Director Distribution
3. Shab-ud-din, Chief Eng. (Distribution) Planning
4. Ghulam Farid, General Manager Operations
5. S. Qalb-I-Hassan Bokhari, Director (Statistics) Distribution

* Includes those met during both the Initiation (January, February 1988) and Master Plan Revision (April - June, 1988) periods.

6. A.A. Legnari, C.E. Distribution and Construction
7. Ishaq Khan, Dir. Dist. Design and Standards
8. M. Nawab Khattak, Gen. Manager Customer Service
9. Munawar Ali Khan, Chief Systems Analyst, Headquarters Computer Center
10. Abdul Bari Qureshi, Director Customer Assistance
11. Sheikh Meraj Ahamad, Director General, Commercial
12. AEB Gujranwala
    i. Sajid Masood Qureshi, Chairman
    ii. Mansoor Hussain, Dep. Dir. Commercial
    iii. C.D. Khokhar, S.E. Sheikhupura
    iv. Abdul Ghaeoor, Dep. Dir. Planning
    v. Mh. Mohyuddihen, Dir. Technical
    vi. M.S. Naeem, S.E. Slalkot
    vii. M. Saleem Khan, S.E. 1st Circle Gujranwala
    viii. Mh. Yousef, S.E. 2nd Circle Gujranwala
    ix. Abdul Mazood Ansari, Dep. Dir.(Electric Plants)
    x. Mh. Anwar, Chief Programmer- Computer Center
    xi. Ahmad Kansar Aghan, Chief Data Control- Computer Center

D. Energy Wing

1. Ashfaq Mahmood, Chief (In Charge)
2. Mohamed Zia-ud-Din
3. Farhan Sabih

E. Other Government of Pakistan

1. Sema Hafeez, Economic Consultant, Planning Commission
M. Akram Khan, Additional Secretary (Power)

F. Government of the Sind

1. Mansur Hashimi, Bureau of Stat. Planning and Dev. Dept (phone)

G. Government of the Punjab

1. Dr. Bashir Ahmad, Chief Economist Planning & Development Dep.
2. Zaka -ud- Din, Chief (Water & Power) Planning & Development Dep.
3. Abdul Aziz Chaudhri Deputy Sec. (Power) Irrigation & Power Dep.
4. Abdul Hafeez, Asst. Chief (Water & Power) Planning & Development Dep.
5. Mohamed Ghulam Qadir, Senior Chief (ECA & H) Planning & Development Dep.
6. Dr. Zafar Altaf, Secretary, Agriculture Department
7. Haroon Rashid Toosy, Director Technical, Power

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H. Government of NWFP

1. Suleman Ghani, Secretary P&D

I. USAID

1. Lahore
   i. Richard Stevenson, Chief Power Dist. Div./Lahore & Regional Affairs Officer
   ii. Shaukat Ali Chughtai, Provincial Liason Officer

2. Islamabad
   i. David Johnston, Office Chief, Energy and Environment
   ii. Jim Bever, Division Chief, Energy Policy and Planning
   iii. John Morgan, Division Chief, Energy Policy (USAID)
   iv. Gene George, Director, Office of Engineering
   v. S. Raza Husain, Program Manager, Energy Planning
   vi. Masood Malik, Sen.Energy Advisor, Planning & Development Project
   vii. M. Shahid Ahmed, Program Manager, Power Distribution
   viii. Tahir Ali, Deputy Program Manager, Power Distribution
   ix. Peter Davis, Office Chief, Programs
   x. Paul Mulligan, Programs Office

3. Washington
   i. Robert Ichord, Chief, Office of Energy and Environment, ANR
   ii. Robert Archer, Office of Energy and Environment, ANR

J. World Bank

1. Ibrahim Elwan, Division Chief, EM1
2. Tasa Kocic, Planning Engineer, EM1
3. Ragu Sharma, Financial Analyst, EM1
4. Mahesh Sharma, Consultant, EM1
5. Christos Christofides, Power Engineer, Technical Department

J. Mathtech

1. James D. Westfield, General Manager

L. PTAT

1. Jim Heifner, Managing Consultant
2. John Andrews, General Manager
3. Michael Knapp, Deputy Managing Consultant
4. T. J. Walker, Chief Consultant P&E

M. Others

1. H. U. Beg, Former Secretary of Finance, GOP
2. Mr. James Wolf, Director, International Irrigation Management Institute, Pak.
3. Andrew Stone, Resident Fellow, International Irrigation Management Institute, Pak.
4. Private Consultants:
   i. Dr. Zanir Fikri, Fikri Associates (FACE)
   ii. A Munis, Fikri Associates (FACE)
   iii. Z. D. Babar, Fikri Associates (FACE)
   iv. M. Saeed Shamsi, Chief Executive, Potential Engineers
   v. Eng. Hasan Javed

APPENDIX A1
STUDY TEAM MEMBERS

Appendix A1

Study Team Members

1. deLucia and Associates:

A. Professional

a. Russell deLucia, President
b. Michael Lesser
c. Martin Wulfe
d. Gerry Dunnion
e. Peter Hayes
f. Christopher LaFarge
g. Lionel Maistre
h. Peter Rogers
i. Douglas W. Smith

B. Support

a. Anthony Bole
b. Gary Fradin
c. Monamed Hanif

2. Fikri and Associates (FACE Ltd), Consulting Engineers

A. Professional

a. Zahir Fikri, President
b. M. A. Munis
c. Zahir ud Din Babar
d. B. A. Azhar
e. Abbas Ali Baig
f. Asad Ali
g. Razi Bashir
h. Saif Ali
i. Nawaz Nasir
j. Hafiz M. Hafeez
k. Monamed Ismail

B. Support

a. Irfan Qadir
b. Touseef Ahmed
c. Inayat Ullah
d. Javed Ahmed
e. Asim Bashir
f. Ishtirq H. Ansari
g. Asghar Ali Malik
h. Shaukat Shah

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APPENDIX B

ESTIMATION OF THE FINANCIAL AND ECONOMIC COST OF ELECTRICITY, GENERATION AND TRANSMISSION

Appendix B

Estimation of the Financial and Economic Cost of Electricity Generation and Transmission

The purpose of this part of the analysis is to estimate generation and transmission (G&T) costs for the financial and economic analyses of different customer and village types. Because rural areas tend to have low load factors, and G&T is particularly capital intensive in Pakistan, the costs of electricity are detailed by capacity and energy (variable) costs. The capacity cost reflects the fixed cost to meet the peak MW demand for electricity and is, therefore, expressed as Rs per MW peak during the system peak period. The energy costs are the variable system costs that are a function of the level of kwh use and is expressed as Rs/kwh. It should be noted that the term "energy costs" is used in this work to cover all variable or recurrent costs such as fuel and O&M.

While this approach of estimating capacity and energy charges addresses the load factor issues, it does not directly address the differences in the costs of electricity between peak and off-peak periods. The costs resulting from this analysis are weighted averages of the peak and off-peak costs. Estimating the LRMC for peak and off-peak electricity is beyond the scope of this study though it should be part of future rural electricity planning along with detailed sectoral peak coincidence analysis. In any case, for this study the last part of this appendix presents estimates which were used in sensitivity analyses.

Financial Costs (historical basis)

As an introduction, it is useful to distinguish between two general approaches to estimating the financial cost of electricity: historical accounting data and replacement (or expansion planning) data. The financial analysis on which this work is based is on the historical approach which is implicit in the data presented by WAPDA in Power System Statistics - Twelfth Issue (Ref 57). The historical approach tends to produce lower costs because it does not capture the effects of future inflation of supply costs and the increasing marginal cost of power generation as lower cost options are exhausted. This approach provides a lower bound on the financial costs of electricity.

Table 3.32 of WAPDA Statistics (Ref 57) provides much of the basic data for 1987:

	Cost/kwh generated (paisa)
Generation	26.7
Transmission	6.2

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Losses at each of these levels over the recent years have been about: 2 percent at generation and 9 percent for transmission (Table 3.30, Ref 57). These data would be sufficient to generate an average cost for generation and transmission of nearly 37 paisa/kwh:

$$((26.7/.98) + 6.2)/.91 = 36.7$$

If average distribution losses of 9 percent are assumed, the G&T cost delivered to the customer becomes about 40 paisa/kwh.

For this work, a more detailed approach was taken for estimating both capacity and energy charges. This was done by first estimating the energy cost based on WAPDA data for fuel and O&M costs, and then estimating the capacity cost as the difference between the total average cost and the energy cost.

The fuel cost for the thermal plants is summarized in Table 1.23 and the O&M costs for both thermal and hydro plants in Table 1.22:

	paisa/kwh (1986-87)
fuel for thermal:	47.8
O&M for thermal :	2.2 (approx)
O&M for hydro :	1 (approx)

Using an average of about 35% thermal and 65% hydro based generation, the average energy (or variable) cost is about 18 paisa/kwh. This energy cost for the current year is probably higher as the percentage of generation based on thermal plants has increased.

Using an average generation cost of about 27 paisa/kwh and an energy cost of about 18 paisa/kwh, the amount available to recover capital costs is about 9 paisa. Using a capital recovery factor (CRF) of 0.15 (discount rate 15%, 30 year life) and an overall load factor of 63.7% (UNDP/WB) Ref 175), the capital cost per kilowatt is about 3350 Rs:

$$(0.09 * .637 * 8760) / 0.15 = 3348$$

This amount of 3350 Rs/kw is obviously only a very approximate estimation. It appears reasonable as it is below the average capital cost of the construction of existing capacity of 3600 Rs/kw (Table 1.5 WAPDA Statistics) as this 3600 figure does not include any depreciation. However, to reflect depreciation, the 3350 result should probably be substantially lower than the 3600 figure. But on the other hand, the difference should be less because the 3350 is per kw-demand and not per kw-installed as is the 3600 figure. The difference between kw-demand and kw-installed is largely the reserve margin so that the cost per kw of demand is about 15 percent higher than per kw installed.

For transmission costs, the total capital cost per kw can be estimated using the above assumptions for the CRF and load factor plus assuming that O&M costs are 7% of total capital costs. The resulting capacity cost is about 1550 Rs/kw and O&M costs are about 2 paisa/kwh:

$$(.0617 * .637 * 8760) / (0.15 + 0.07).$$

In summary, the capacity cost for generation and transmission is the sum of Rs. 3350 and 1550 divided by the power losses. Assuming a 5% loss, the total is about 5200 Rs/kw delivered to the customer. Using energy costs of 18 and 2 paisa/kwh for G&T respectively along with losses of 2 and 9 percent respectively for G&T, the energy or recurrent costs are about 22.3 paisa/kwh. With another 9 percent losses for distribution, the total recurrent cost is about 24.5 paisa/kwh.

Since the capital cost is estimated here as a residual between total and recurrent costs, it is very sensitive to these numbers. In general, a range of results could be determined by varying all of the above assumptions. Furthermore, the same results can be produced by different assumptions such as lower capital costs and higher losses. Consequently, sensitivity analysis has been performed.

Financial Costs (replacement costs)

The above financial costs are based on historical data, not on replacement costs or a "forward-looking" system expansion analysis. Consequently these costs are significantly less than financial replacement or economic costs. As discussed in the next subsection of this appendix, economic costs are significantly higher than the above financial costs: nearly six times the capital charge and about 2.5 times the energy charge. Although a replacement financial cost analysis was not done, such financial costs are probably very similar to the economic costs presented below. Part of the reason for this similarity is the lack of a shadow premium on foreign exchange.

Economic Costs

The basic data used for the estimation of the long-run marginal costs of electricity were primarily from the UNDP/World Bank, Power System Planning Study for Pakistan,, draft report, February 1987 (Ref 175. This study estimated the LRMC to be about $0.042/kwh (0.42/kwh (page 82) in 1986 (when the exchange rate was 16.5 Rs/$), using a discount rate of 4.7%. Re-estimating this result using a 10% discount rate and 17.5 Rs/$ leads to a LRMC of about 0.96 Rs/kwh. This result does not adjust for 1986 vs. 1988 costs. The conversion to a 10% discount rate was done by calculating the incremental unit costs at both discount rates for the base case cash flow (page 52, Ref 175).

The ratio of the results using 10% and 4.7% was 1.31. This cost is similar to one obtained via personal communications with the World Bank of 0.9 Rs/kwh which was based on private sector estimates. For the purposes of this study an average LRMC of generation of 0.9 Rs/kwh is used. Sensitivity analysis was used to examine the effects of different results. The base case expansion plan used is presented in Tables B-1 through B-4 at the end of this Appendix. Table B-1 provided the demand forecast; Table B-3 the expansion costs.

The next step was to estimate the capacity and energy charges that are compatible with this average cost. The capacity charge was estimated using the UNDP/WB work on the base case for expansion and demand (pages 27 and 52). Using the time streams of the construction costs, 25% of the O&M costs (the assumed fixed portion) and the incremental MW demand, the average capacity cost is about $1400/kw-demand at a 10% discount rate. Using 10%, a 40 year average Rs in 1986. Using the energy costs (fuel and 75% of O&M) and the incremental kwh demand, the same procedure results in an energy cost of about 0.43 Rs/kwh. The total of these two numbers (.45 + .43 = .88) is slightly less than the above total of 0.96 because it is a long-run average cost not a marginal cost. Another possible source of distortion was the use of somewhat different scenarios.

Based on this work, the 0.9 Rs/kwh cost is broken down approximately into 0.45 each for energy and capacity. The capacity cost was converted to a capital cost using 15%, 40 years and 63.7% load factor, resulting in about 25,000 Rs/kw-demand. Adjusting for a 20% reserve margin, this falls at the high end of the very broad range of Rs/kw-installed presented in Appendix III (page 28-29) of Ref 175.

The estimation of the transmission costs was done by assuming that transmission capital costs are equal to 15% of generation costs. This percentage is probably low (however the generation cost seems high) and is much lower than in the financial analysis (the financial results have a particularly high percentage). The result of about 3750 Rs/kw is over twice the financial historical cost of about 1550 Rs/kw. Using an O&M cost for transmission of 7% of total capital, the recurrent cost for transmission is about 4.5 paisa/kwh.

In summary, the estimated economic capacity charge for generation and transmission using about 5% power losses is about 30,000 Rs/kw-demand delivered to the customer:

$$(25,000 + 3750) / (1 - 0.05)$$

The estimated economic energy charge is about 55.4 paisa before distribution losses:

$$(45/0.99 + 4.5) / 0.91$$

With 9% distribution losses, the energy charge becomes about 61 paisa/kwh. Sensitivity analysis involving these results will be performed.

The importance of having developed both capacity and energy charges can be seen by comparing the difference between the system average at a load factor of 53.7 percent and the rural system at a load factor of 25 percent. Examining only generation with capacity charge of 25,000 Rs/kw and energy charge of 0.45 Rs/kwh, the system overall average cost is about 0.93 Rs/kwh while a rural system overall average is about 1.67 Rs/kwh. These calculations are based on energy charges of 0.45/(1-.02) to account for generation losses, and unit annualized capital charges using 10% discount rate, 25 years and the load factors.

Peak and Off-Peak Economic Costs of Electricity

Without doing detailed analysis on the dispatch schedule of plants and without a power system expansion analysis exploring marginal costs under peak, intermediate and base load conditions, there are some techniques for estimating peak costs in an approximate manner. One method performed here is the estimation of electricity costs from a peaking plant: combustion turbine using high speed diesel (HSD). Most of the basic data for this plant were taken from the UNDP/WB study (Ref 175):

- Capital cost: $460/kw (in 1986$) with 25 year life.
- Heat rate: 3185 kcal/kwh (based on natural gas, implies overall efficiency of about 27%).
- O&M (variable) costs: $ 3/mWh

In addition to these data, the other basic assumptions are:

- Discount rate: 10% (capital recovery factory of 0.1061 for 25 years).
- Diesel price: $30/bbl delivered or $ 21.11/million kcal.
- Diesel price change: 1 percent increase annually (leads to average fuel cost increase of 13.5 percent over the life of the plant).
- Annual load factor: 25 percent (implies 2190 hours/year).
- Capacity reserve margin: 15 percent (leads to 15 percent increase in capital costs per kw-demanded).

Based on these data, the resulting generation costs are:

Annualized capital cost:	0.027 $/kwh
Fuel & O&M cost:	0.080
Total Generation Cost:	0.107 $/kwh
at 17.5 Rs/$:	1.9 Rs/kwh

Table B-1: Forecasted Annual Peak and Minimum Load, Energy and Load Factor (Ref 175)

Year	Peakload MW	Gr. Rate %	Min. Load MW	Gr. Rate %	Energy GWh	Gr. Rate %	Load Factor %
1987	5,537.3	-	1,994.7	-	30,386.9	-	63.67
1988	6,071.5	9.6	2,186.9	9.6	33,363.6	9.6	63.67
1989	6,642.0	9.4	2,392.4	9.4	37,043.5	9.4	63.67
1990	7,250.5	9.2	2,611.6	9.2	40,439.4	9.2	63.67
1991	7,898.1	8.9	2,844.8	8.9	44,051.4	8.9	63.67
1992	8,586.1	8.7	3,092.6	8.7	47,888.1	8.7	63.67
1993	9,315.1	8.5	3,355.2	8.5	51,954.7	8.5	63.67
1994	10,086.3	8.3	3,633.0	8.3	56,256.0	8.3	63.67
1995	10,900.5	8.1	3,926.3	8.1	60,797.2	8.1	63.67
1996	11,751.6	7.8	4,232.8	7.8	65.544.1	7.8	63.67
1997	12,660.7	7.7	4,560.3	7.7	70,614.6	7.7	63.67
1998	13,593.6	7.4	4,896.3	7.4	75,817.9	7.4	63.67
1999	14,600.6	7.4	5,259.0	7.4	81,434.3	7.4	63.67
2000	15,643.3	7.1	5,634.6	7.1	87,249.9	7.1	63.67
2001	16,757.1	7.1	6,032.1	7.1	93,406.4	7.1	63.67
2002	17,917.3	7.0	6,453.8	7.0	99,935.3	7.0	63.67
2003	19,156.0	6.9	6,899.8	6.9	106,841.9	6.9	63.67
2004	20,467.5	6.8	7,372.2	6.8	114,156.8	6.8	63.67
2005	21,854.7	6.8	7,871.8	6.8	121,893.8	6.8	63.67
2006	23,321.2	6.7	8,400.1	6.7	130,073.2	6.7	63.67
2007	24,870.4	6.6	8,958.1	6.6	138,713.8	6.6	63.67
2008	26,506.0	6.6	9,547.2	6.6	147,836.3	6.6	63.67
2009	28,251.8	6.6	10,176.0	6.6	157,573.5	6.6	63.67
2010	30,050.2	6.4	10,823.8	6.4	167,603.9	6.4	63.67

Table B-2: Base Case Optimal Expansion Plan (Case 1) (Ref 175)

Year	Unit Name	Size (MWe)	Type	Fixed Addition
1987				
1988	Guddu CC	2x300	Combined Cycle	Yes
1989	Jamshoro 1	1x250	Oil Steam	Yes
	COTU	4x100	Combustion Turbine	No
1990	Mangla 9-10	2x100	Hydro	Yes
	Pipri 2	2x210	Oil Steam	Yes
	Koc Addu CC	2x300	Combined Cycle	Yes
	Jamshoro 2	2x210	Oil Steam	Yes
	Multan - Reh.	4x55	Oil Steam	Yes
	Faisalabad - Reh.	2x53	Oil Steam	Yes
	Guddu - Reh. 1	2x102	Natural Gas	Yes
	Guddu - Reh. 2	1x210	Natural Gas	Yes
	Sukkur - Reh.	4x12	Natural Gas	Yes
	Quetta - Reh.	2x8	Coal Steam	Yes
	Kotri GT - Reh.	2x12	Natural Gas	Yes
	Faisalabad CC	2x140	Combined Cycle	No
1991	Tarbela 11-14	4x432	Hydro	Yes
	Pipri	1x210	Oil Steam	Yes
	Multan	1x210	Oil Steam	Yes
	Site CC	1x126	Combined Cycle	Yes
	Low Head Hydro 2	1x200	Hydro	No
1992	Multan	2x210	Oil Steam	Yes
	Low Head Hydro 2	1x100	Hydro	No
1993	Oil Plant	1x300	Oil Steam	No
	Imported Coal	2x460	Coal Steam	No
	Low Head Hydro	1x100	Hydro	No
1994	Imported Coal	2x460	Coal Steam	No
1995	Imported Coal	2x460	Coal Steam	No
1996	New Hydro 1	4x300	Hydro	No
	Tarbela 15-16	2x432	Hydro	No
1997	Imported Coal	1x460	Coal Steam	No
	Combined Cycle	1x300	Combined Cycle	No
	Tarbela 17	1x432	Hydro	No
	New Hydro 1	2x300	Hydro	No
1998	Oil Plant	1x300	Oil Steam	No
	Imported Coal	1x460	Coal Steam	No
	New Hydro 1	2x300	Hydro	No
1999	Imported Coal	2x460	Coal Steam	No
	Combined Cycle	1x300	Combined Cycle	No

Table B-2 (Continued): Base Case Optimal Expansion Plan

Year	Unit Name	Size (MWe)	Type	Fixed Addition
2000	Oil Plant	1x300	Oil Steam	No
	Imported Coal	2x460	Coal Steam	No
2001	Imported Coal	1x460	Coal Steam	No
	New Hydro 2	1x354	Hydro	No
2002	New Hydro 2	3x354	Hydro	No
2003	New Hydro 3	1x932	Hydro	No
2004	Oil Plant	1x300	Oil Steam	No
	Imported Coal	1x460	Coal Steam	No
2005	Oil Plant	2x300	Oil Steam	No
	New Hydro 3	1x932	Hydro	No
2006	Oil Plant	1x300	Oil Steam	No
	Imported Coal	3x400	Coal Steam	No
2007	Fluidized Bed	2x40	Coal Steam	No
	New Hydro 3	1x932	Hydro	No
	New Hydro 4	1x645	Hydro	No
2008	Imported Coal	4x460	Coal Steam	No
2009	Oil Plant	1x300	Oil Steam	No
	New Hydro 3	1x932	Hydro	No
	New Hydro 4	1x645	Hydro	No
2010	Oil Plant	2x300	Oil Steam	No
	Imported Coal	1x460	Coal Steam	No
	New Hydo 5	1x1207	Hydro	No

Table B-3: Cash Flow Summary for the Base Case (Ref 175)

CASH FLOW-CONSTANT VALUE
MILLIONS US$

CASE: WITH KALABAGH
D.R.: 4.7%

	YEAR	CONSTRUCTION COST ANNUAL	CONSTRUCTION COST CUMULATIVE	FUEL COST ANNUAL	FUEL COST CUMULATIVE	O & M COST ANNUAL	O & M COST CUMULATIVE	TOTAL COST ANNUAL	TOTAL COST CUMULATIVE
1	1987	115.7	115.7	534.1	534.1	102.0	102.0	751.8	751.8
2	1988	256.4	372.1	615.4	1149.5	111.5	213.5	983.3	1735.1
3	1989	273.3	645.4	736.8	1886.3	123.1	336.6	1133.2	2868.3
4	1990	520.6	1166.0	716.2	2602.5	145.0	481.6	1381.8	4250.1
5	1991	788.0	1954.0	646.7	3249.2	180.5	662.1	1615.2	5865.3
6	1992	846.0	2800.0	735.4	3984.6	191.8	853.9	1773.2	7638.5
7	1993	715.1	3515.1	797.7	4782.3	212.8	1066.7	1725.6	9364.1
8	1994	669.5	4184.6	899.2	5681.5	233.0	1299.7	1801.7	11165.8
9	1995	760.6	4945.2	1010.1	6691.6	254.7	1554.4	2025.4	13191.2
10	1996	1031.5	5976.7	961.7	7653.3	289.2	1843.6	2282.4	15473.6
11	1997	1345.3	7322.0	1007.1	8660.4	319.5	2163.1	2671.9	18145.5
12	1998	1459.4	8781.4	1071.8	9732.2	343.3	2506.4	2874.5	21020.0
13	1999	1157.3	9938.7	1214.0	10946.2	368.0	2874.4	2739.3	23759.3
14	2000	873.5	10812.2	1360.3	12306.5	392.5	3266.9	2626.3	26385.6
15	2001	987.3	11799.5	1432.3	13738.8	419.7	3686.6	2839.3	29224.9
16	2002	1115.9	12915.4	1333.6	15072.4	459.7	4146.3	2909.2	32134.1
17	2003	1723.3	14638.7	1414.8	16487.2	483.9	4630.2	3622.0	35756.1
18	2004	1694.7	16333.4	1619.6	18106.8	508.1	5138.3	3822.4	39578.5
19	2005	1991.5	18324.9	1725.6	19832.4	536.7	5675.0	4253.8	43832.3
20	2006	1763.9	20088.8	1931.6	21764.0	572.4	6247.4	4267.9	48100.2
21	2007	1186.0	21274.8	1947.1	23711.1	603.8	6851.2	3736.9	51837.1
22	2008	765.6	22040.4	2171.5	25882.6	645.5	7496.7	3582.6	55419.7
23	2009	218.9	22259.3	2217.9	28100.5	680.5	8177.2	3117.3	58537.0
24	2010			2242.2	30342.7	712.5	8889.7		

Table B-4: Amount, of Fuel Needed During 1987-2010 (Case 1) (Ref 175)

AMOUNT OF FUEL NEEDED DURING 1987 2010
BASE CASE WITH KALABAGH (N (4.7% DISCOUNT RATE)

YEAR	DOMESTIC COAL COST (1000's)	DOMESTIC COAL AMOUNT TONS(1000's)	DOMESTIC COAL COMULATIVE TONS(1000's)	IMPORTED COAL COST	IMPORTED COAL AMOUNT TONS (10E6)	IMPORTED COAL COMULATIVE TONS (10E6)	FUEL OIL COST (1000's)	FUEL OIL AMOUNT BARRELS(10E6)	FUEL OIL COMULATIVE BARRELS(10E6)	NATURAL GAS COST (1000's)	NATURAL GAS AMOUNT 10E9 CFT	NATURAL GAS COMULATIVE 10E9 CFT
1987	3095	75.673	75.673	0	0.000	0.000	262590	14.350	14.350	200243	74.270	74.270
1988	2910	71.150	146.822	0	0.000	0.000	262844	14.364	28.714	233275	86.522	160.792
1989	3051	74.597	221.419	0	0.000	0.000	316351	17.288	46.002	323641	119.038	280.830
1990	3186	77.898	299.317	0	0.000	0.000	450895	24.641	70.642	253675	94.089	374.919
1991	2705	66.137	365.454	0	0.000	0.000	480416	26.254	96.896	155883	57.817	432.736
1992	2638	64.499	429.953	0	0.000	0.000	563743	30.807	127.704	159964	59.331	492.066
1993	2363	57.775	487.729	151342	2.389	2.389	557553	30.469	158.173	82984	30.779	522.845
1994	2005	49.022	536.751	302669	4.778	7.167	527503	28.827	187.000	63601	23.590	546.435
1995	1961	47.946	584.697	454424	7.174	14.341	486625	26.593	213.593	63541	23.493	569.928
1996	1958	47.873	632.570	436223	6.887	21.228	464853	25.403	238.996	55585	20.616	590.544
1997	2034	49.731	682.302	500829	7.907	29.135	441109	24.106	263.102	59645	22.122	612.666
1998	[illegible]	49.780	732.082	567809	8.964	38.099	446543	24.403	287.504	[illegible]	[illegible]	[illegible]
1999	1977	48.338	780.420	717087	11.321	49.419	458258	25.043	312.547	32553	12.074	644.043
2000	0	0.000	780.420	873099	13.784	63.203	461303	25.209	337.757	21485	7.969	652.012
2001	0	0.000	780.420	944709	14.914	78.117	455520	24.893	362.650	27154	10.071	662.083
2002	0	0.000	780.420	912750	14.410	92.527	401017	21.915	384.565	17243	6.395	668.479
2003	0	0.000	780.420	916914	14.475	107.002	452189	24.711	409.276	41453	15.375	683.854
2004	0	0.000	780.420	1072466	16.931	123.933	469477	25.656	434.932	59929	22.243	706.096
2005	0	0.000	780.420	1142848	18.042	141.975	475324	25.976	460.907	76980	28.552	734.648
2006	0	0.000	780.420	1238666	19.555	161.530	632154	34.546	495.453	52901	19.621	754.269
2007	6257	152.984	933.403	1228832	19.400	180.930	633722	34.632	530.085	69646	25.832	780.101
2008	5427	132.690	1066.093	1389613	21.938	202.867	741835	40.540	570.625	51015	18.921	799.022
2009	6203	151.663	1217.757	1385699	21.844	224.712	784702	42.882	613.507	59638	22.120	821.142
2010	4337	106.040	1323.796	1510755	23.850	248.562	701913	38.358	651.865	32820	12.173	833.315

APPENDIX C
ESTIMATING KEROSENE USE AND BENEFITS OF ELECTRICITY SUBSTITUTION IN RURAL HOUSEHOLDS

Appendix C

Estimating Kerosene Use and Benefits of Electricity Substitution In Rural Households

In principle, there are three ways to estimate RE benefits in Pakistan: These methods are:

1: To estimate the demand curve for electric power using econometric techniques:

2: To estimate the displaced fuels and avoided costs, in particular, kerosene and diesel fuel and related equipment:

3: To estimate the benefits from sales beyond displacement of alternatives by summing revenues and estimating consumer surplus benefits which are not captured by revenues:

Due to the past arrangements for the operation of RE in Pakistan it is not feasible to econometrically estimate the demand curve for rural consumers in Pakistan: We are therefore using a combination of methods 2 and 3 for the Master Planning work: Our preliminary work on estimating household benefits has demonstrated the need for the following information and clarifications:

1: Kerosene Displacement

The following sections of this appendix explain the methodological issues which must be addressed in estimating how much kerosene is displaced by RE in Pakistan: These attachments are based on systematic review of the previous studies of this issue, and on the numbers used by previous analyses of RE and kerosene displacement in Pakistan:

In principle, a large proportion of the benefits created by electrifying rural households can be calculated by measuring the displacement of kerosene by electrical appliances providing the same services: The only substantial displacement is for lighting: For this calculation, all that is needed is an estimate of the current level of household kerosene use and rates of change of use (plus or minus); the financial and economic prices of kerosene; and similar figures for electrical lighting:

In practice, however, such calculations are subject to great uncertainty: A review of the information available to the team reveals a wide spread as to estimates of these crucial parameters:

A crucial parameter in this method is the rate at which kerosene lamps use fuel: We have attempted to reduce the uncertainty in this parameter by running a kerosene lamp until it burns one litre of kerosene: This simple test revealed that a standing chimney lamp runs at about 0:02 litres of kerosene per hour: A small wick lamp would use even less fuel--probably no more than 0.01 litre per hour: Additional tests are continuing:

As indicated below, most analyses (including the 1977 AID Studies and the 1982-84 Area Master Plans) used a much higher rate of kerosene use per lamp-hour (ranging from 0:08 to 0:16 litres per hour) than were derived from our tests: More comprehensive testing is therefore required (see chapter 6):

Related to this are the behavioral assumptions about consumer substitution of electrical for kerosene lighting: Additional studies are required to determine:

(1d) Number of kerosene lamps displaced by one bulb:

(1e) Wattage of bulbs installed by low and high income users:

(1f) Amount of kerosene displaced in volumetric terms:

2: Use Rates

The rate of growth of actual electrical energy consumption of RE consumers is critical in the calculation of benefits, especially the benefits from consumer surplus. A steep demand curve generates a very different quantity of consumer surplus than a flatter demand curve:

If the actual demand curve of rural consumers is steep, then the area of consumer surplus benefits is obviously much less than if the curve is gentle: The difference is accounted for by the rate at which the rural consumer uses electrical energy after displacing kerosene:

<u>It is therefore crucial that realistic estimates be obtained of how fast consumer demand for electrical energy increases over time:</u>

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This appendix describes three ways of estimating kerosene use in Pakistani rural households: They are: 1) field surveys 2) expenditure surveys and 3) physical calculations based on use assumptions: As will be seen, the estimated kerosene use varies widely according to which method is used:

a: Field Surveys of Kerosene Use

Typical District Area Plans give kerosene consumption in "bottles:" For example, District Area Plan for Malakand and Sahiwal Districts are shown in Table C-1:

Table C-1: Kerosene Consumption for Three Illustrative Households

	Household 1	Household 2	Household 3
Malakand (Ref 152):			
Village Electrified?	No	Yes	Yes
House Electrified?	No	No	Yes
Bottles Kerosene/Year	177	165	39
Income, Rs/Year	16,596	11,257	18,487
Percent of Kerosene Used for Cooking	3:4	6:3	33
Sahiwal (Ref 150):			
Bottles Kerosene/Year	110	71	40
Income, Rs/Year	10,682	6,123	16,318

The Malakand Survey provides a further breakdown of the usage rate assumptions used in economic analysis in Pakistan RE planning: Annex G (Ref 152) states that the average kerosene use is 127 litres per year: This number suggests that a bottle contains less than one litre: Recent surveys by this RE team indicate that a bottle is approximately :7 litre in one Sahiwal village:

There are apparent inconsistencies in the data in the Malakand report: For example, at the cited use rate of 0:12 litres/hour of kerosene lamp lighting, the household would receive 1,058 hours of lighting, not the 1,460 stated: At the 1,058 hours level, the use level would be 3, not the cited 4 hours per day.

The Malakand survey rates were used in sensitivity analysis for high estimates for kerosene use, since the kerosene use rates for lighting cited in the Area Master Plan surveys appear high by other South Asian standards: In low income rural households in Bangladesh, surveys show annual lighting kerosene use to be about 28 litres/household: In India, a national low income rural household estimate is 25 litres/year, and for high income, 51 litres/year: In Sri Lanka, the range for all rural households is 96-104 litres/year: In addition, Leach cites a 1983 survey for all rural households in Pakistan which gives an annual kerosene lighting use rate per household of 34 litres, about one quarter the FACE figure: (REF 88, p: 75):

b: Kerosene Rural Use Rates, Expenditure Surveys.

There two sources available from expenditure surveys in Pakistan. One is the 1985 expenditure survey of the Federal Bureau of Statistics. The other is Leach's treatment of the FBS 1979 and 1985 statistics which provides further insight due to his access to the original data:

The Household Income Survey Report (REF 141, p: 294:) is a national survey that estimates rural household kerosene expenditures for Pakistan in 1984-85 at average 11 Rs/month: At 3:5 Rs/litre, this corresponds to 38 l/y: Of this, a substantial portion is used for cooking, as noted above with reference to Malakand (Leach also estimates that 85 percent of rural HH kerosene usage is for lighting, REF 130, p.10).

If it is assumed that 85 % of kerosene usage is for lighting as a conservative estimate (since the total for rural households includes electrified households and households using neither electricity nor kerosene), the national rural average figure is therefore 0:85 x 38 or 32 litres/year:

According to the survey, use rates do not vary much across regions, being 12 % less in the Punjab, 6 % greater in the Sind, 29 % greater in NWFP, and 12 % greater in Baluchistan: (REF 141, p: 294): But use rates do vary greatly across income levels: The survey reports that the households with the lowest income levels spent 6:44 Rs/m on kerosene, or 22 litres/year on kerosene, which amounts to 0:85 x 22 or 19 l/year on kerosene for lighting: The highest income group spent about 3 times as much on kerosene, or 18:23 Rs/m, which amounts to 54 l/year on kerosene lighting (REF 141, p: 294):

According to the Leach study, the average rural household use of kerosene in both 1979 and 1985 was estimated at about 57 l/year (REF 130, p: 15). Using the 85 % figure referred to above for lighting usage, this suggests a figure of 49 l/year of kerosene used for lighting: Obviously, this figure is substantially higher than the 32 l/y calculated above from the 1985 Survey, although it is still only 40% of the FACE estimate of 127 l/year:

Leach also provides data from the December 1980 Housing Census Report. In that year, kerosene was reported to light about 83% of the 9:1 million rural households in Pakistan: (The figure is estimated at 86% in both the Sind and the Punjab, which together account for 1:6 and 5:5 million respectively, or 78 % of the total rural households) (REF 130, p: 130).

c: Physical Estimates of Kerosene Lighting Use

Some sources on Pakistani RE do not begin with surveys of use or expenditure rates: Instead, they begin with assumed hours of kerosene lighting, and apply conversion and equivalence ratios to calculate kerosene usage (and thereby, displaced kerosene by the RE program): As will become evident, there are serious methodological problems associated with this procedure: The key issues are: relative lighting service (intensity and other qualitative factors); number of kerosene and electrical points required for substitution to be effected; and estimations of kerosene use rates: Only the third factor, use rates, is a physical constant: Unfortunately, its value in Pakistan is highly uncertain, at least in the sources reviewed for this report:

Relative lighting intensity

A 60 W bulb clearly provides much more illumination than a kerosene lamp: The World Bank estimates that a 60 W bulb generates 20 percent more light intensity than a pressure kerosene lamp, while it provides 90-96 percent more light intensity than a standing lamp: (Light intensity is measured in foot candles at 30 cm) (REF 88, p: 77): But consumers do not appear to substitute for kerosene lamps based on strict lighting equivalence: If they did, they would acquire tiny electrical bulbs of 2-4 W: There is no reason to assume, therefore, that the lighting intensity equivalence ratios provide any guidance as to the rate at which light bulbs will displace kerosene lamps: Nor does relative lighting intensity indicate the wattage of substituting light bulbs:

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Number of Lights

Conceptually, the number of lights in a HH could be a function of desired lighting levels and number of spaces and planes which require lighting: There is no physical basis for assuming a 1:1 or a 2:1 correspondence of kerosene lamp to light bulb: This is a consumer decision which can only be known by site specific surveys:

For example, in 1982, AID estimated displaced kerosene assuming that 2-60 W bulbs would displace a single kerosene lamp using 0:16 l/hour at 3 h/day of operation (REF 26, Annex, Attachment A, p:B): Yet informal enquiry reveals that rural households do not operate kerosene lamps in that ratio to light bulbs: Rather, common practice is more likely to be the use of only one lamp, while 2-4 light bulbs may be used (the number used for planning purposes):

It should be noted that in Indonesia, where detailed micro-surveys of this issue have been conducted under AID auspices, Weatherly found that the actual substitution ratio was 1-60 W bulb per high pressure Petromax lamp: If one 60 W bulb substitutes for one relatively expensive lamp in Indonesia, then how many inferior kerosene lamps fusing (using kerosene at a much lesser rate) is a 60 W bulb likely to displace in Pakistan?

And why use 60 W bulbs in an analysis of Pakistan? Is that the practice? Unfortunately, no survey information is available at this time on the actual wattage level of bulbs in rural electrified households: With both the real wattage and ratio of displaced lamp/light bulbs unknown, the cost of displacing kerosene lamps is impossible to determine: As the rate at which the kerosene lamps use kerosene is also subject to debate (see below), we are left with three unknowns and an undertemined system:

Use Rate of Kerosene

In the AID 1982 calculation, kerosene displacement per lamp was estimated at 213 l/year -- no less than 1:7 times the FACE estimates of kerosene lighting use: (REF 26, Annex O, Attachment A, p: B): Likewise, Gellerson estimates kerozene use per household in Pakistan to be even higher at 360 l/consumer prior to electrification (REF 87, p: 211):

Obviously, one cannot displace more kerosene than surveys show is actually used: It may be that the fueling rate of kerosene lamps in Pakistan is not correctly estimated in these various studies: FACE and AID both used kerosene lamp fueling rates above 0:1 litres/hour: However, World Bank estimates (REF 88, p: 77) are much lower:

Fishcan Wick	:	0:0098 l/hour
Standing Kerosene lamp	:	0:012 l/hour
Hurricane lamp	:	0:0121 l/hour
Pressure lamp	:	0:0478 l/hour

Even if the World Bank estimate if off by a factor of 100% (assuming uncut wick, draughty conditions in rural Pakistani households), use rates for standing kerosene lamps would be 0:02 l/h, not 0:1: The figure of 0:1 l/h also corresponds to that found in detailed field surveys for Petromax lamps in Indonesia (REF 106, p: 107): The fueling rate makes a tremendous difference to the displaced kerosene in the econimic calculation: More precise estimates of the actual field fueling rates are needed for the range of kerosene lamps used by Pakistani rural households:

The early estimates based on FACE burning tests have provided very preliminary estimates: More lamps need to be tested under various operating conditions:

Using the information available to date, estimates have been based on surveys of initial energy usage by newly electrifying households and an asumed growth rate of that usage; initial consumer power load, coincidence or diversity factors; and assumed growth rate of power load: In the Area Master Plan surveys, however, the estimates of electrical energy household usage combine all electrified households, regardless of how long they have been electricity users, and regardless of their income: Moreover, the Area Master Plan surveys measured only appliance ownership, not actual kwh usage of electrified households:

The following studies are urgently needed (see chapter 6):

(2a) Rural household electricity usage starting from the year of electrification for as long as a time series is available:

(2b) These data are needed for low and high income electrified households:

(2c) Data in (2a) and (2b) for representative villages from all four provinces:

(2d) An indication of the accuracy of rural usage billing records based, for example, on a comparison of grid station electricity flow records with metering records:

(2e) Actual (absolute) rate of household connections from year 1 of electrified villages, for as long as time series are available, for representative villages in all four provinces:

Customer connections have been constrained in many villages by institutional arrangements and provincial selection criteria: This suggests that the a"average" rate of connection may not be as meaningful as the range of connection rates for villages which have had electricity for the same number of years:

Therefore, the following must be studied in detail:

(2f) For representative villages from all four provinces <u>with same years of electrification</u>, the range of actual rate of household connections,

(2g) Measurements of actual coincidence factor of village load:

It is understood that in many villages, more than one household is served by a given connection to a dwelling-courtyard complex: If this is often the case, then the overall number of connected households may be understated in the above estimates for (2d) or (2e).

(2h) The incidence of "multiple household" connections which should be applied to estimates for items (2d) and (2e) to correct for understatement of real connection rate:

(2i) The incidence that village-industrial (for example, flour mills) and village-commercial (that is, small shops and the like) are actually adjuncts to household connections, thereby inflating household energy use statistics as might be available:

With this information, it will be possible to better derive a meaningful demand curve for estimating the consumer surplus portion element of benefits of RE in Pakistan:

3: Estimating Consumer Surplus

With the information described above, the consumer surplus can be estimated using two separate techniques:

<u>Willingness-to-Pay</u>

The first technique is to estimate consumer willingness-to-pay (WTP) for electricity: WTP is measured by asking potential and actual consumers in electrified and non-electrified villages the question: "how much are you willing to pay for electricity service?"

<u>Appliance Use</u>

The second way to estimate the full benefits of RE service to consumers above their service bills is to estimate their annual cost for end-use appliances:

SUMMARY

1. Gellerson (REF 87) suggests that RE displaces 360 litres of kerosene per year per electrical connection:

2: AID PP 1982 used 0:16 l/h, which implied a kerosene lamp used 213 l/y: (1 kerosene lamp is assumed to run 3:5 h/d, 365 d/y):

3: One of the 1978 RE Assessments (the only one to date available to the Team) states that kerosene lamp fueling rate is 0:14 l/hour (REF 142, P: 6:10).

4: A typical FACE report uses 0:08 l/h in the economic evaluations, which implied a kerosene lamp used 102 l/y (they actually set h/d at 3, rather than the 3:5 used by AID PP 82, but I have adjusted for the difference here by using 3:5 h/d, 365 d/y):

5: The World Bank Household Energy Paper suggests the following use rates for different types of kerosene lamps:

Table C-2: World Bank Kerosene Lamp Fueling Estimates

Fishcan Wick	:	0:0098 l/hour
Standing Kerosene lamp	:	0:012 l/hour
Hurricane lamp	:	0:017[illegible] l/hour
Pressure lamp	:	0:0478 l/hour

Note: annual rates calculated 3:5 h/d, 365 d/y:

During a test conducted by FACE, a typical standing kerosene lamp consumed one litre of kerosene in 47 hours, or at a rate of 0:02 l/h: It is therefore concluded that a more realistic kerosene lamp fueling rate is 0:01-:02 l/h in Pakistan: <u>This realistic kerosene lamp fueling rate is 8-16 times less than AID PP 82, and 4-8 times less than FACE used in the Area Master Plan:</u>

Cross-check for this Conclusion

Another way to approach the kerosene displacement issue is to take the National Income and Expenditure Survey figures for 1985 and convert them to physical use rates/household:

The NIES estimates that the average, all-Pakistan kerosene expenditure is 11 Rs/m: At the price (at the time of the study) of 3:5 Rs/l, the average rural Pakistani household bought about 38 litres of kerosene/year: Some of this would be devoted to cooking or wood-lighting, some to rural commercial uses (run out of the household budget), so the kerosene used for lighting, after adjusting for such factors, might be approximately 85 percent of the total, or 32 litres of kerosene/year per rural household:

Gerald Leach massaged the raw data in his Household Energy report to AID last year. He estimated average rural kerosene household use at 57 litres per year. After the same adjustments in above for cooking etc, his figure for the income-derived use rate of kerosene for lighting only was 49 l/year, including both electrified and non-electrified households. Leach also reports elsewhere a 1983 survey which showed use rates to be about 34 l/year (adjusted by 0.85 for cooking etc, this would be about 29 l/year) per all-Pakistan rural household.

Which figure is more accurate? Gellerson's 360 l/year? AID 1982 estimate of 213 l/y per lamp? The estimate by FACE of 102 l/year per lamp? The Income Survey of 32 l/year per household? Leach's 49 l/year per household? The 1983 survey of 29 l/year? The RE team's calculation based on physical assumptions of 38 l/y (1.5 kerosene lamps per household, 3.5 h/d, 365 d/y at 0.02 l/h of kerosene light for poor households)?

One way to cross-check is to multiply the household use rate by the rural population of 11 million and check against the total (urban and rural) domestic kerosene use according to the Energy Yearbook. This figure accounts for 99 percent of kerosene use, according to the Yearbook. Table C-3 shows the Yearbook's estimates for national domestic kerosene use since 1981-82.

The kerosene fueling rates and annual rural household kerosene use rates are summarized in Table C-4. There, they are compared with the national actual kerosene use rates where known for the year of the estimate.

Plainly, one cannot use estimates that propose that rural households use more kerosene than is used by the total household sector in Pakistan, let alone the nation. Nor can one displace this non-existent kerosene by RE. Whatever the correct level of kerosene displacement, the actual displacement for electrified households should not include the kerosene which electrified households continue to use (estimated at 20 percent in some Area Master Plans).

Leach estimates that urban kerosene use is about 76 l/year per urban household. (As with the rural estimate of 49 l/year, this figure includes electrified and non-electrified households). There being 4 million urban Pakistani households in 1985, urban households account for about 304 million litres of the total for 1985, which was probably about 850 million that year (10% growth on the figure shown above for the previous year). The total (850 million litres) minus the urban (304 million litres) leaves 546 million litres for rural household kerosene consumption for cooking and lighting.

Table C-3: National Kerosene Data

Use	81-82	82-83	83-84	84-85	85-86	86-87
Total Use						
Thousand Tonne	554	604	690	760	811	878
Million Liters	620	677	773	851	908	983
Domestic Use						
Thousand Tonne	544	594	679	748	801	861
Million Liters	698	763	872	960	1028	1106

Source: REF 171, pp. 32-33.
Note:

Other Government makes up the difference between total and domestic use for each year except 1986-87, where transport also appears as a kerosene user for the firsttime. No allowance for commercial kerosene use seems to have been made. In reality, therefore, national domestic kerosene use is likely to be substantially less than the figure cited above. This factor has not been accounted for in determining a credible indicative household kerosene rate elsewhere in this text. As adjustment for this factor would further reduce the level of household kerosene use which could be displaced by rural electrification, this procedure is biased toward rural electrification.

Table C-4: **Kerosene Displacement Parameters**

A	B	C	D	E	F
Source	Kero Lamp Fuelling Rate l/h kero Lamp Lighting	Estimated Kero Used in Lighting	Resulting Estimate of Total Rural Lighting Kero Use, million l/y	Total Kero for Pakistan Domestic Household Kero Use, Cooking + Lighting, (urban + rural for year of Estimate in D, million/y	Ratio of E/D for Year of E in which estimate in D was made
Gellerson 82	unknown	360 $l/y\text{-}HH^{-1}$	3,960	698	3.7
AID 82 PP	0.16	213 l/y (one lamp)	3,514	698	5.0
NESPAK 78	0.14	179 $l/y\text{-}HH^{-1}$	1,967	510 (698 x (0.73)	3.9
FACE 83-84	0.08	102	1,683	872	1.9
NIES 85	11 Rs/m, 3.5 Rs/l	38 $l/y\text{-}HH^{-1}$	352	960	0.4
Leach 87 for 85	n/a	49 $l/y\text{-}HH^{-1}$	539	960	0.6
1983 Survey	n/a	29 $l/y\text{-}HH^{-1}$	374	763	0.5
RE Master Plan 1988	0.02	55 $l/y\text{-}HH^{-1}$	605	960	0.6

Notes:

1. Rates x 1.5 lamps/household x 3.5 h/d x 365 d/y x 11 million rural HH in 1984-5 when NIES and Area Master Plan Surveys conducted.
2. Where the rate was given by source referred to in text per lamp rather than per household-year, we have put these estimates on the same footing by converting them to 1.5 kerosene lamps per household at 3.5 h/d, 365 d/y.
3. National domestic kerosene use from Energy Yearbook, converted to liters at 45 MJ/kg kerosene; 37.6 MJ/l kerosene; liters/kg kerosene = 1.28.
4. Team 88 is for a 1985 estimate using 11 million population. Strictly, rural population for the years of each estimate/kerosene use ratio should have been used. As these were not immediately available to the Team in Lahore, the adjustment was ignored. It would have not affected the results significantly.

In Table C-4, the estimate by Leach for rural household lighting is 539 million litres. Re-inflating the Leach estimate for the estimated 15% used for cooking in rural households generates a total rural kerosene usage of 642 million. At this rate, Leach urban/rural total domestic household kerosene use would be 304 + 642 million litres = 942 million litres. This figure is therefore somewhat high, but at least an approximation of the national use for the domestic sector that year of about 850 million litres. Leach's figures are therefore acceptable as estimates, being most consistent with physical cross-checks for lamp fueling rates, population estimates, and national kerosene use.

Estimates used in past analysis are useful for illustrative purposes but should be discounted in evaluating future RE programs in Pakistan. It is imperative that more precise and accurate field data be collected in a range of Pakistani villages, representative of varying cultural and environmental conditions.

Techniques for such data collection are available although few field studies in the past have used the rigorous methods (physical measurement) necessary for reliable estimates.

APPENDIX D
ESTIMATION OF HOUSEHOLD AND COMMERCIAL SECTOR BENEFITS AND COSTS

Appendix D

Estimation of Household and Commercial Sector Benefits and Costs

The household benefits were estimated in two parts: (1) from substitution of electricity for kerosene for basic lighting and (2) from the use of electricity for additional lighting and for new appliances. The substitution benefits are based the cost savings approach, i.e., on the value of kerosene not consumed and the amount of equivalent electricity used. The benefits from electricity use for new activities is based on the consumer surplus approach. This method estimates benefits as the area under a straight line demand curve using two points.

Low Income Households

For the low income households, the amount of kerosene consumed for lighting was assumed to be 50 liters annually based on two lamps burning 3.5 hours daily consuming 0.2 liters kerosene per hour. Using a kerosene price of 4 Rs/liter, the potential savings are 200 Rs. of kerosene and 38 Rs. of lantern related equipment. Given the un-reliability of electricity and the portability of kerosene lamps, it is assumed that only 90 percent of the potential savings are attained, or about 215 Rs. From these savings must be deducted the cost of electric bulbs which is estimated to be 60 Rs. annually based on a use rate of about 8 bulbs per year. Therefore, the total savings is about 154 Rs. annually.

An important issue is the definition of the electricity equivalence for basic lighting. Assuming that the kerosene lamps are equal to a 60 watt bulb leads to a high implied electricity use and therefore a low implied value per kwh. Based on a comparison of the lumens emitted by the two different light sources, many of the small kerosene lamps (e.g. wick type) are equivalent to, at most, a 25 watt bulb and probably much less (Ref 88). Using a 25 watt bulb as equivalent to a kerosene lamp, the yearly electricity consumption is 64 kwh and its value at about 2.4 Rs/kwh.

The estimation of the additional benefits had several steps. The first step was to estimate total annual kwh use. Based on a review of available information as discussed in Appendix C, a use rate of 20 kWh/month or 240 kWh/year was chosen to be illustrative. This choice was based on the aggregate use data and on the construction of a scenario of appliance use that matches this rate. This breaks down into 64 kwh for basic lighting and 176 kwh for other use. One scenario for this other use level corresponds to (i) a 50 percent increase in basic lighting (possibly 50 percent more hours daily leading to 32 extra kwh), (ii) an additional 60 watt bulb for 3.5 hours/day, and (iii) a 60 watt fan used 1200 hours/year. The peak demand for all electricity use would be .36 kw (two 25 watt and one 60 watt bulbs plus 60 watt fan).

The benefits associated with this additional use of 176 kwh was estimated based on a simplified demand curve using two points: the one for kerosene substitution, where price = 2.4 Rs/kwh and quantity = 64 kwh and the other for total use, where price = 1.81 Rs/kwh and quantity = 240 kwh. The final price 1.8 Rs/kwh is based on all initial costs (such as connection) as well as the tariff. Based on the demand curve, the benefits for the additional use beyond the basic lighting were estimated to be about 371 Rs. Therefore, total benefits were estimated to be 525 Rs (or the sum of 154 from savings and 371).

The basis for the price at the second point on the demand curve of 1.8 Rs/kWh is the sum of the tariff plus the annualization of the connection cost, wiring, and all unofficial charges. These costs were annualized at 15% over 30 years using an approximate factor of 0.15:

Connection	1200 * 0.15	=	180 (Rs/Year)
Wiring	300 * 0.15	=	45
Unofficial Charges	750 * 0.15	=	113
	Total		338

At 240 kWh/Year:	338 / 240	=	1.40 Rs/kWh
Tariff:			.39
			1.79 Rs/kWh

Average Income Households

The same approach was used as for the low income households. For basic lighting (the first point on the demand curve), the same figures were used: 64 kWh at 2.4 Rs/kWh. The additional benefits were based on an estimated total annual use rate of 540 kWh, or 476 kWh for non-lighting uses:

Iron	125 kWh
Fans	150
Extra Lighting	200
	475 kWh/Year

The basis for the price at the second point on the demand curve of 1.1 Rs/kWh is the sum of the tariff plus the annualization of the connection cost, wiring, and all unofficial charges. These costs were annualized at 15% over 30 years using an approximate factor of 0.15:

Connection	1200 * 0.15	=	180 (Rs/Year)
Wiring	500 * 0.15	=	75
Unofficial Charges	750 * 0.15	=	113
	Total		368

At 540 kWh/Year:	368 / 540	=	0.68 Rs/kWh
Tariff:			.39
			1.07 Rs/kWh

From the demand curve, the benefits were 835 Rs/Year. Adding the benefits from savings of Rs 154, the total benefits come to about 990 Rs/Year, or 1.8 Rs/kWh at 540 kWh/Year.

High Income Households

Again using the same approach as above, the benefits from basic lighting are estimated at 100 l/year (at a price of 4.0 Rs/l) plus the cost of equipment of Rs 80, or 480 Rs/Year. Because kerosene lanterns are portable and electric lights generally are not, only 90% of these benefits are estimated to be attributable to electricity, or about 430 Rs/Year. Deducting Rs 130 for bulb costs, the total for basic lighting is therefore about Rs 300/Year. The consumption for basic lighting is estimated as the use of 4 bulbs for 3.5 hours per night, each at about 30 watts average, or 150 kWh/Year. The average cost (for the first point on the demand curve) is therefore 300/150, or 2.0 Rs/kWh at 150 kWh.

The basis for the price at the second point on the demand curve of 0.73 Rs/kWh is the sum of the tariff plus the annualization of the connection cost, wiring, and all unofficial charges. These costs were annualized at 15% over 30 years using an approximate factor of 0.15:

Connection	1500 * 0.15	=	225 (Rs/Year)
Wiring	1000 * 0.15	=	150
Unofficial Charges	1000 * 0.15	=	150
	Total		525

At 1800 kWh/Year:	525 / 1800	=	0.29 Rs/kWh
Tariff:			.44
			0.73 Rs/kWh

The average tariff paid of 0.44 Rs/kWh is based on 50 kWh per month at the first block rate of 0.39 Rs/kWh and the remaining 100 kWh per month at the next block rate of 0.46 Rs/ kWh.

The total benefits were 2580 Rs/Year from the demand curve, plus 300 from savings, or Rs 2880 per year. At a usage rate of 1800 kWh per year, this is an average of 1.6 Rs/kWh.

Commercial Establishments

The benefits for basic lighting for commercial users was the same as for average income households, regardless of whether a refrigerator was used or not, or Rs 300. The additional benefits for those without a refrigerator were also the same as for the average income households except that the second point of the demand curve was at 2.25 Rs/kWh:

Tariff	1.28 Rs/kWh
FAS	.22
Annualized Capital Costs	0.75
	2.25 Rs/kWh

Where the capital costs include:

Connection	1200 Rs
Wiring	500
Unofficial Costs	1000
	2700 Rs

Annualized using the 0.15 factor, over 540 kWh brings the annualized capital costs to 0.75 Rs/kWh.

The total benefits to commercial establishments without refrigerators are therefore about 1110 from the demand curve plus 155 from savings, or 1265 Rs/Year. This is equivalent to about 2.34 Rs/kWh.

For commercial establishments with refrigerators, the analysis is the same except for an additional 350 kWh/year for the refrigerator. Thus the second point on the demand curve is at 890 kWh at a price of 1.96 Rs/kWh:

Tariff	1.28 Rs/kWh
FAS	.22
Annualized Capital Costs	0.46
	1.96 Rs/kWh

Where the capital cost per kWh is the same as for commercial establishments without refrigerators, but spread out over additional usage. The total benefits for this consumer group is 1800 Rs/year from the demand curve and 155 from savings, or 1955 Rs/Year. This is equivalent to about 2.20 Rs.

APPENDIX E
ESTIMATION OF TUBEWELL IRRIGATION BENEFITS AND COSTS

Appendix E

Estimation of Tubewell Irrigation Benefits and Costs

1. General Introduction to Pumping in Pakistan

There are approximately 280,000 tubewells currently. Of the existing stock of tubewells, about 120,000 (43%) are electric, and the remaining 160,000+/- (57%) are diesel. About 30,000 of these are high speed diesel (HSD), and 130,000 low speed (LDO)(1).

About 10-12,000 new tubewells are installed annually. Of these, roughly half are HS, and the rest are electric. There are apparently very few LS diesels being installed today. At present, there are at least three sizes of HS diesel engines available in the marketplace, a 12, 13 (2) and 36 hp Dong Feng engines marketed by PECO, of which the 12 hp is apparently the most prevalent.

TABLE E-1: Distribution of Pump-Sets by Province

Punjab	84%
Sind	11%
NWF Province	2%
Baluchistan	3%

In the Sind and Punjab, most of the water table depths are in the 3-15 meter range, and thus the use of one and two stage centrifugal pumps is possible. The cost/benefit analysis for tubewell electrification must address the issue of diesel vs. electric prime mover capital cost, O&M cost, and energy (fuel) cost both from a financial and economic perspective. The well installation cost, and the farm system costs, are not a function of the type of prime mover, but are examined for this analysis to determine the proportion of the tubewell cost represented by the pump-set, and with respect to affordability of conversion from existing diesel to electric.

In NWFP, virtually all of the well installation will have to be very deep wells. These are virtually unknown for agricultural use at present, although they may exist for water supply use. For very deep wells, submersible (turbine) pumps must be used, and these are electric by definition. As issues

(1) Based on estimates by FACE, WAPDA electric tubewell connection figures, and 1985 Agricultural Statistics of Pakistan, figures adjusted for growth for years between 1985 and 1988.

(2) The 13 hp engine is similar to the 12 hp, except for a more sophisticated cooling system.

regarding electrification benefits in NWFP are addressed, the relevant comparison should be between an electrified tubewell, and from a diesel generator, both using an electric turbine pump, and no irrigation at all. In general, the break even point between connection cost and diesel under this comparison will favor electric for a greater distance from the nearest 11 kV line as a function of the additional cost of the generator between the diesel and the pump.

At the time of this analysis, little data were available regarding tubewells in Baluchistan. More information needs to be collected and analyzed concerning the average and distribution of the sizes of pump lifts in Baluchistan.

2. Financial and Economic Costs - Illustrative Cases

The impact of converting tubewells from diesel to electric has been analyzed from both a financial and economic perspective. In general, electric tubewells are much less costly on an annual basis from a financial perspective than HS or LS diesel wells of similar capacity. On an annual economic cost basis however, electric wells appear to be roughly similar to diesel. This difference appears to be driven by two costs. First, the total investment including connection charges is greater for electric than for diesel. Second, under current tariff policies and pumping practices, the economic price of electricity appears to be far greater than the financial price, whereas the price difference is relatively slight for middle distillate fuels. These results are discussed in greater detail in this Appendix for three representative cases based on the 'typical' tubewell installation described below, with variations on these base cases for system head, etc.

The three cases, electrification of existing low speed diesel installation, electrification of existing high speed diesel, and comparison of high speed diesel vs electric for a new installation, reflect the current stock of tubewells and the fact that most of new wells being installed today are apparently either HSD or electric. The increased availability of HSD has apparently displaced LDO engines for new installations. Conversion from electric to diesel is not addressed in this discussion for two reasons: first, if the well is electrified, the major connection cost has already been made; and second, since the financial cost of electricity appears to be so far below its economic cost, the financial cost of electric tubewell operation is significantly below that of a diesel tubewell. Although there are at least 156,000 tractors (3). They are not used as the prime mover (i.e., power take off) for tubewells, although the are used as a backup prime mover for out of service prime movers.

(3) Census of Agricultural Machinery, 1984

For each of the three cases, a typical and a possible example are presented. The typical well reflects the current practice of over-sizing the prime mover (electric and LDO), and average efficiencies for the major pump-set components (4). The 'possible' example reflects somewhat better sizing of the prime mover, to the extent possible, and pumpset component efficiencies for a well maintained and correctly loaded (esp. properly laid out pipe system) pump-set.

The economic life assumptions are based on the teams best judgement for each of the major components. The financial discount rate reflects market rates for debt. Foreign exchange capacity figures are based on interviews with pump and engine manufactures and include not only the direct foreign exchange for parts, but the embodied foreign exchange in the imported raw materials, e.g, iron.

For this model, we calculate the system head (lift height plus friction head) of the tubewell, and then calculate the hp requirement for the prime mover based on efficiency assumptions for the other major components of the pump-set, pump, and transmission. This times the engine efficiency is used to generate the fuel/energy consumption/hr.

Capital costs are based on price lists from KSB and PECO for HSD and LSD engines, electric motors, and pumps in the appropriate sizes. The connection costs have been provided by FACE (5), and adjusted in the financial analysis for the WAPDA Rs 30,000 credit. A foreign exchange shadow price factor is used to adjust the economic cost of these components using the direct and embodied foreign exchange component is calculated for each of the major capital components of the pump-set. A 20% duty on imported materials for industrial importers is also built into the calculations.

Operator and maintenance (O&M) costs for both HSD and LDO engines are based on 1:12 ratio for lubricating (mobil) oil to fuel oil use rate, and labor and repair costs which are drawn for interviews with farmers (FACE). The O&M cost is comparable to those found in the example tubewells in the District Master

(4) Drawn from Ref 140. Field testing of these component efficiencies, as well as the effecr of retrofitting existing tubewell installations, is part of an ENERCON study now underway.

(5) These figures are also consistent with those presented in the FIZAC, Private Tubewell and Rural Electrification Project, Reconnaissance Report, May 1984.

Plans, e.g., an average of Rs 5.3/hr (labor plus other O&M) for diesel and Rs 1/hr for electric (6) (see table E-2). Fuel cost as described above is based on the power requirement of the pump adjusted for the engine efficiency divided by the energy content of the fuel requirement per hr (annual charges not based on consumption are include with O&M). Annual electric consumption for tubewells at given prime mover horsepower ratings, and utilization levels are with 10% - 15% of the model's calculated annual consumption (7). The total cost per acre ft. for is also within 5% of the figure given in the FIZAC reconnaissance report (8) adjusted for inflation.

TABLE E-2: Cost Comparisons:

	Model (Typical)	Range (9)
O&M (Labor & Other)		
DIESEL	4.81/hr	0.87 - 10.97 /hr
ELECTRIC	1.11/hr	0.43 - 6.08 /hr
Fuel & KWH		
HSD	3.33/hr	3.0 - 4.5 l/hr
LDO	3.73/hr	3.6 - 6.0 l/hr
ELECTRIC	8,297 KWH/yr	3,984 - 15,666 KWH/yr

These figures can not be correlated with system head, or efficiency, as insufficienr information is given in the tables.

Typically, if the prime mover is LS diesel, the engine would be 16-18 hp, if HS, then 12 hp. Thus there would necessarily be over capacity in the prime

(6) Master Plan for Rural Electrification in Pakistan - Sind Province, Baharalpur.

(7) Private Tubewell Development Project, Working Paper for the Review Meeting. World Bank, April 1987, p.38.

(8) Private Tubewell and Rural Electrification Project, Reconnaissance Report, FIZAC, May 1984. Rs 200/acft in 1983 rupees. At 5% inflation rate, Rs 255 in 1988 rupees. The model's cost/acft (HSD) is approximately Rs 287/acft.

(9) Rural Electrification Master Plan - Sahiwal (Ref 150).

mover, although not necessarily in the pump. Electric motors come in a much broader range of sizes, particularly at the lower hp ratings, and thus in this range an electric motor can be a sized more appropriately for a 1 cusec well. However, 15 hp is the most common size for electric motors in tubewells of this size, since many farmers still apparently believe bigger is better and will pump more water. In addition, the oversized motor is less likely to burn out, and the marginal cost of the addition rated hp is relatively small. For the proposes of this model, the cost structure of the tubewell is assumed to be constant regardless of prime mover choice (10).

Efficiencies of tubewells are very low due to a variety of factors in addition to the over-sizing of the prime mover discussed above. Pumps are often not sized properly for the cusec delivery, head, or hp of the tubewell for which they are installed. In addition, the suction and discharge pipes are frequently not installed correctly creating unnecessary frictional losses and increasing the total system head.

A variety of operating and maintenance issues can also decrease the efficiency of the diesel engine. The most common problems include, operating below rated speeds, and at loads well below rated capacity, improper lubrication, low coolant water temperature, faulty injector, etc. These factors can increase diesel consumption for a given load by a factor of two or more (11).

Electric tubewells suffer from the same range of ills discussed above for diesel tubewells. With electrification, however, another set of issues is raised. Tubewells represent about 20% of total demand for electricity, and 23% of peak demand, with very wide seasonal variations. Some sources have suggest that tubewells could account for upwards of 70% of rural demand during peak pumping periods. Thus load management becomes a major issue for rural electrification.

Electric prime movers are preferred over diesel because operations and maintenance are substantially easier. Diesel engines can be difficult to start, require regular inputs of fuel oil and lubricating oil, and are messy to deal with. Electric motors, on the other hand, require only the flip of a switch to start, and require much less maintenance.

(10) There is a small variation in transport costs between diesel and electric.

(11) Ref 119.

The major problem with electric motors is the unreliability of the electric supply. This has two consequences. First, unplanned interruption of supply interferes with irrigation timing, and mean that electrified tubewell operators may have to maintain a backup prime mover, either engine or tractor PTO. For the purposes of this model, we have not included the cost of a second backup prime mover based on the simplifying assumption that tractor PTO is available as part of the overall farm system. Second, voltage fluctuations can burn out motors. Part of the farmers' rational for over-sizing motors is greater protection against burn out. Once burned out, the motors can be rewound. This cost is include in 'other O&M' based on rewinding the motor every other year at a cost of about Rs 2,000. However, poor quality of materials together with improper rewinding often lead to motor efficiencies far below the design efficiency of the original product, and thus the real cost of rewinding may be significantly greater than that of the rewinding itself. This together with the installation related inefficiencies and low power factors due to over-sizing can lead to very low overall system efficiencies.

For a typical tubewell, however, such as the one described below the hp requirement is in the 5 - 10 hp range. If the prime mover is sized correctly, the capital cost is reduced. with in the range of 50%-100% loading, the fuel/energy consumption per hp.hr is relatively constant. However, for an LDO diesel under the possible conditions, the turn down appears to go below the 50% loading which leads to diminished efficiencies, and thus higher fuel consumption per hp.hr within this range. At lower system heads as well, the loading may be fall below 50%, and the prime mover efficiency may be significantly affected.

CASE #1: High speed diesel vs. electric (New installation)

For shallow wells (lift height no more than 15 ft. (5 m) the pump and prime mover are often both located at the surface. For most tubewells, however, the pump is located below the grade, about 15 ft+/- above the water table. The following is an illustrative example which is the basis of the economic and financial cost model presented below. The physical, financial and economic parameters chosen typify many of the tubewell installations in Pakistan, and provide a basis for understanding the benefits and cost of electrification for tubewells (12):

(12) This is for the Punjab and Sind which together account for 95% of all installed tubewells. It is drawn from interviews with FACE, ACC, and Dr. Khalid of Faisal University and the Farm Machinery Institute.

- o Depth to water 25 ft. (8 m) (13)
- o Pump located 10+/- ft below grade
- o if the prime mover is diesel, the engine is located at the surface, with a belt drive to the pump.
- o if the prime mover is electric, the motor is generally located with the pump.

For a water demand of 1 cusec, and a system head of 35 ft, the power required would be about 9.2 hp for diesel and 7.2 hp for electric (14). Tubewells commonly range from 1/2 cusec to 1 1/2 cusec, and 1 cusec was chosen since it seems to be prevalent.

CASE #2: Low speed diesel to electric - Retrofit

The case for conversion for an existing 18 hp light diesel oil pump-set to an electric pump-set is examined. For this case, a 15 hp is assumed for the typical example, and a 10 hp motor for the potential example, as it would be sufficient to handle the load under typical conditions without being significantly oversized. The fuel and KWH cost, and the O&M cost are calculate in the same manner as in the first case. The capital cost calculation for the retrofit includes the value/opportunity cost of resale of the diesel engine, the cost of a new motor plus the cost of re-fitting the pump with a high speed impeller, and new transmission.

CASE #3: High speed diesel vs. electric - Retrofit

The difference between this model and that for the HSD/electric comparison is entirely in the basis of the annual capital cost calculation which is similar to that in Case #2.

3. Load Management

Electric tubewell pump-sets, and in particular, the motors tend to be oversized due to a) farmers' belief that a bigger prime mover will mean more water, b) the unreliability of the power supply, and c) the relatively cheap

(13) This is typical of wells outside the command area, and falls within the top 28% of wells within the canal command area.

(14) This reflects the difference in the assumed prime mover efficiencies. The model assumes that the pumpset is operating at capacity while in operation, which may artificially increase the fuel cost calculations. This increase will be mitigated to some extent by the reduced efficiencies at low loadings.

incremental purchase cost of larger hp motors. In general, the load factor of these units is low. This is a result of load characteristics, as well as motor design. On average, it could be reckoned that between 15% to 20% additional KVA capacity could be freed by improving the power factor on these installation to between 85% and 90%. This could be done by WAPDA, or the tubewell owner (operator) fitting a suitably sized capacitor to the motor.

In addition to improving the efficiency of these installations while operating, tubewell load should be shifted off peak. This could be done by either interrupting supply to these tubewells for the peak period, and by installing double tariff meters. The interruptible tariff should contain a capacity (low power factor) surcharge, a tariff which already applies to B1 and B2 industrial users but explicitly excludes tubewells. In the US, this is done by installing time-switches to the meters and only recording maximum demand during nominated peak periods, providing financial incentives for using electricity off-peak, analyzing pump-set efficiency to determine how overall efficiency can be improved, and lastly by examining the water usage and farming system to determine if the farm demand for water pumping can be reduced (15).

4. Water Demand

Direct energy use in irrigation can be influenced in two basic ways. First, it is possible to increase the efficiencies of the pumping systems currently in use or contemplated. This is the operating assumption behind the calculations above.

Second, the total amount of water used for irrigation purposes could be reduced by modest changes in the agricultural practices. This would require a greater understanding of the ecology of the farming system. Traditionally, the solution to low apparent productivity and droughty conditions has been irrigation together with petrochemical inputs (fertilizers, pesticides, etc.). Irrigation while it provides short and sometimes medium term improvements in productivity, does so at the cost of increased cost of production, and does not address the fundamental problems. The response should be is better soil management. Irrigation, in fact tends to create a number of problems with the farm system, most of which are now increasingly in evidence in Pakistan. These are water-logging of soils, salinity, both in the root zone, and in the surface and ground water, and much increased loss of nutrients from the root zone (16).

Although there are several projects which have and are addressing the problem of water losses for the canal, and on-farm irrigation systems, e.g., evaporative losses, and seepage losses from the distribution ditches, there has apparently been very little, if any, attention paid to the demand for water by the cropping system, or to what changes could be instituted to affect this demand.

(15) From P,G, & E Agricultural Load Management Program, and Gary Kah (personal communication)

(16) Ref 140, Sec 2.1.1

FINANCIAL/ECONOMIC ANALYSIS OF TUBEWELL PRIME MOVER COSTS * 30-May-88
CASE #1: High Speed Diesel vs. Electric - New Installation 12:54 PM

(All prices in Pak. Rs)		HSD Typical	HSD Possible	ELECTRIC Typical	ELECTRIC Possible
Discharge = 1.00 cusec					
Lift height = 25 ft					
Suction/discharge Effic. =		70.0%	65.0%	70.0%	65.0%
System Head =		35.7 ft	29.4 ft	35.7 ft	29.4 ft
Pump Efficiency =		55.0%	70.0%	55.0%	70.0%
Transmission Efficiency =		80.0%	85.0%	95.0%	95.0%
Motor/Engine Efficiency =		17.5%	25.0%	70.0%	80.0%
Overall Pumpset Efficiency		5.4%	12.6%	25.6%	45.2%
Power Req. (Sh Hp) =		9.2 hp	5.6 hp	7.8 hp	5.0 hp
Engine/Motor size =		12 hp	12 hp	15 hp	10.0 hp
Utilization (Hrs/yr)		1,000 hrs	1,000 hrs	1,000 hrs	1,000 hrs
Utilization rate (%)		11.4%	11.4%	11.4%	11.4%
CAPITAL COST: (1)					
Diesel engine life = 7 yrs				Motor life = 8 yrs	
Discount Rate (ECON) = 10.0%				Pump life = 12 yrs	
Discount Rate (FIN) = 15.0%				Connection = 30 yrs	
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%		Unsk%		FE%	Unsk L%
Prime Mover Cost	40%	8,124	8,124	35% 9,000	6,600
Pump Cost	35%	4,700	4,700	35% 4,700	4,700
Connection Cost (2)		—	—	20% 50,750 30%	50,750
Annualized Cap Cost (FIN) for pumpset		2,820	2,820	2,873	2,338
for pumpset + connection				6,033	5,498
Annualized Cap Cost (ECON) for pumpset		2,177	2,177	2,210	
for pumpset + connection				6,231	5,812
OPERATOR/MAINTENANCE:					
Labor Shadow Price factor =		0.9			
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%				FE%	
Labor (unskilled)		3.50 /hr	3.50 /hr	0.50 /hr	0.50 /hr
Lube oil (Cost/hr)	60%	4.43 /hr	1.89 /hr	—	—
Lube oil (ECON Cost/hr)	50%	2.53 /hr	1.08 /hr	—	—
Other O&M/hr	5%	0.75 /hr	0.75 /hr	5% 0.61 /hr	0.61 /hr
Annual O&M cost (FIN)		8,675	6,136	1,109	1,109
Annual O&M cost (ECON)		6,168	4,863	1,022	1,022
ENERGY COST:					
High Speed diesel oil - MJ/l		37.4			
Fuel (Energy) Consumption/hr		3.79 l	1.62 l	8.3 KWH/H	4.7 KWH/H
Total Fuel (Energy)/yr		3,793 l	1,617 l	8,297 KWH	4,697 KWH
Financial Cost/unit (4)		4.00 /l	4.00 /l	0.80 /KWH	0.80 /KWH
Economic Cost/unit (5)*		3.25 /l	3.50 /l	1.60 /KWH	1.60 /KWH
Annual Energy Cost (FIN)		15,172	6,468	6,637	3,758
Annual Energy Cost (ECON)		12,327	5,659	13,275	7,516
TOTAL FINANCIAL COST		26,667	15,424	13,779	10,365
NET BENEFIT	ANNUAL			12,888	5,059
	/UNIT			1.55 /KWH	1.08 /KWH
TOTAL ECONOMIC COST		20,672	12,699	20,528	14,350
NET BENEFIT	ANNUAL			145	(1,652)
	/UNIT			0.02 /KWH	(0.35)/KWH
TOTAL FINANCIAL COST ELECTRIC				3,982	3,447
GROSS BENEFIT (FIN)	ANNUAL			22,685	11,977
	/UNIT			2.73 /KWH	2.55 /KWH
TOTAL ECONOMIC COST ELECTRIC				3,233	2,815
GROSS BENEFIT (ECON)	ANNUAL			17,439	9,884
	/UNIT			2.10 /KWH	2.10 /KWH

*Note: The economic cos of electricity used in this table is a prelim inary estimate which indicates an approxima break-even cost betwee diesel and electricity under the typical example. Later estima of the economic cost of electricity are hi er. See Table 3.4-1 related text for thes results.

NOTES:
(1) Assumes that well cost is independant of pumpset type.
(2) Connection cost of Rs 40250, initail cost of 10,000 plus wiring of 500.
(4) Includes fuel surcharge of Rs 0.22/kwh.
(5) Includes distribution losses, area distribution charges and RE O&M costs.

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FINANCIAL/ECONOMIC ANALYSIS OF TUBEWELL PRIME MOVER COSTS * 09-Jun-88
CASE #2: Low Speed Diesel (light diesel oil) vs. Electric - Retrofit 03:37 PM

(All prices in Pak. Rs)		LDO Typical	LDO Possible	ELECTRIC Typical	ELECTRIC Possible
Discharge = 1.00 cusec					
Lift height = 25 ft					
Suction/discharge Effic. =		70.0%	85.0%	70.0%	85.0%
System Head =		35.7 ft	29.4 ft	35.7 ft	29.4 ft
Pump Efficiency =		55.0%	70.0%	55.0%	70.0%
Transmission Efficiency =		80.0%	85.0%	95.0%	95.0%
Motor/Engine Efficiency =		17.5%	22.5%	70.0%	80.0%
Overall Pumpset Efficiency		5.4%	11.4%	25.6%	45.2%
Power Req. (Sh Hp) =		9.2 hp	5.6 hp	7.8 hp	5.0 hp
Engine/Motor size =		18 hp	18 hp	15 hp	10.0 hp
Utilization (Hrs/yr)		1,000 hrs	1,000 hrs	1,000 hrs	1,000 hrs
Utilization rate (%)		11.4%	11.4%	11.4%	11.4%
CAPITAL COST: [1]					
Diesel engine life = 12.5 yrs remaining				Motor life = 8 yrs	
Discount Rate (ECON) = 10.0%				Pump life = 12 yrs	
Discount Rate (FIN) = 15.0%				Connection = 30 yrs	
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%		Unsk%		FE%	Unsk L%
Prime Mover Cost	40%	19,800	12,186	35% 9,000	6,600
Prime mover resale value	50%	9,900	6,093	0	0
Pump Cost	35%	0	0	35% 1,880	1,880
Connection Cost [2]		--	--	20% 50,750	30% 50,750
Annualized Cap Cost (FIN)		1,798	1,107	5,513	4,978
Annualized Cap Cost (ECON)		1,308	805	5,846	5,427
OPERATOR/MAINTENANCE:					
Labor Shadow Price factor =		0.9			
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%				FE%	
Labor (unskilled)		3.50 /hr	3.50 /hr	0.50 /hr	0.50 /hr
Lube oil (Cost/hr)	60%	4.36 /hr	2.06 /hr	--	--
Lube oil (ECON Cost/hr)	90%	2.49 /hr	1.18 /hr	--	--
Other O&M/hr	5%	1.13 /hr	1.13 /hr	5% 0.61 /hr	0.61 /hr
Annual O&M cost (FIN)		8,980	6,688	1,109	1,109
Annual O&M cost (ECON)		6,504	5,325	1,022	1,022
ENERGY COST:					
High Speed diesel oil - MJ/l		38			
Fuel(Energy) Consumption/hr		3.73 l	1.77 l	8.3 KWH/H	4.7 KWH/H
Total Fuel(Energy)/yr		3,733 l	1,768 l	8,297 KWH	4,697 KWH
Financial Cost/unit [3]		3.50 /l	3.50 /l	0.80 /KWH	0.80 /KWH
Economic Cost/unit [4]*		3.00 /l	3.00 /l	1.60 /KWH	1.60 /KWH
Annual Energy Cost (FIN)		13,066	6,189	6,637	3,758
Annual Energy Cost (ECON)		11,199	5,305	13,275	7,516
TOTAL FINANCIAL COST		23,845	13,984	13,259	9,845
NET BENEFIT	ANNUAL			10,586	4,139
	/UNIT			1.28 /KWH	0.88 /KWH
TOTAL ECONOMIC COST		19,011	11,435	20,143	13,965
NET BENEFIT	ANNUAL			(1,131)	(2,531)
	/UNIT			(0.14) /KWH	(0.54) /KWH
TOTAL FINANCIAL COST ELECTRIC				3,461	2,927
GROSS BENEFIT (FIN)	ANNUAL			20,383	11,057
	/UNIT			2.46 /KWH	2.35 /KWH
TOTAL ECONOMIC COST ELECTRIC				2,848	2,430
GROSS BENEFIT (ECON)	ANNUAL			16,163	9,065
	/UNIT			1.95 /KWH	1.92 /KWH

NOTES:
[1] Assumes that well cost is independant of pumpset type.
[2] Connection cost of Rs 40250, bribe of 10,000 plus wiring of 500.
[3] Includes fuel surcharge of Rs 0.22/kwh.
[4] Includes distribution losses, area distribution charges and RE O&M costs.

* Note: The economic cost for electricity used in this table is a preliminary estimate which indicates an approximate break-even cost between diesel and electricity under the typical example. Later estimates of the economic cost of electricity are higher. See Table 3.4-1 and related text for these results.

FINANCIAL/ECONOMIC ANALYSIS OF TUBEWELL PRIME MOVER COSTS *
CASE 4T: High Speed diesel vs. Electric - Retrofit

21-May-88
10:56 AM

(All prices in Pak. Rs)		HSD Typical	HSD Possible	ELECTRIC Typical	ELECTRIC Possible
Discharge = 1.00 cusec					
Lift height = 25 ft					
Suction/discharge Effic. =		70.0%	85.0%	70.0%	85.0%
System Head =		35.7 ft	29.4 ft	35.7 ft	29.4 ft
Pump Efficiency =		55.0%	70.0%	55.0%	70.0%
Transmission Efficiency =		80.0%	85.0%	95.0%	95.0%
Motor/Engine Efficiency =		17.5%	25.0%	70.0%	80.0%
Overall Pumpset Efficiency		5.4%	12.6%	25.6%	45.2%
Power Req. (Sh Hp) =		9.2 hp	5.6 hp	7.8 hp	5.0 hp
Engine/Motor size =		12 hp	12 hp	15 hp	10.0 hp
Utilization (Hrs/yr)		1,000 hrs	1,000 hrs	1,000 hrs	1,000 hrs
Utilization rate (%)		11.4%	11.4%	11.4%	11.4%
CAPITAL COST: (1)					
Diesel engine life = 3.5 yrs remaining				Motor life = 8 yrs	
Discount Rate (ECON) = 12.0%				Pump life = 12 yrs	
Discount Rate (FIN) = 15.0%				Connection = 30 yrs	
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%				FE%	Unsk L%
Prime Mover Cost	40%	8,124	8,124	35% 9,000	6,600
Prime mover resale value	50%	4,062	4,062	0	0
Pump Cost	35%	0	0	35% 1,880	1,880
Connection Cost (2)		—	—	20% 50,750 30%	50,750
Annualized Cap Cost (FIN)		1,575	1,575	5,513	4,978
Annualized Cap Cost (ECON)		1,370	1,370	6,672	6,223
OPERATOR/MAINTENANCE:					
Labor Shadow Price factor =		0.9			
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content -> FE%				FE%	
Labor (unskilled)		3.50 /hr	3.50 /hr	0.50 /hr	0.50 /hr
Lube oil (Cost/hr)	60%	4.43 /hr	1.89 /hr	—	—
Lube oil (ECON Cost/hr)	90%	2.53 /hr	1.08 /hr	—	—
Other O&M/hr	5%	0.75 /hr	0.75 /hr	5% 0.61 /hr	0.61 /hr
Annual O&M cost (FIN)		8,675	6,136	1,157	1,157
Annual O&M cost (ECON)		6,168	4,863	1,022	1,022
ENERGY COST:					
High Speed diesel oil - MJ/l		37.4			
Fuel(Energy) Consumption/hr		3.79 l	1.62 l	8.3 KWH/H	4.7 KWH/H
Total Fuel(Energy)/yr		3,793 l	1,617 l	8,297 KWH	4,697 KWH
Financial Cost/unit (3)		4.00 /l	4.00 /l	0.80 /KWH	0.80 /KWH
Economic Cost/unit (4) *		3.25 /l	3.50 /l	1.60 /KWH	1.60 /KWH
Annual Energy Cost (FIN)		15,172	6,468	6,637	3,758
Annual Energy Cost (ECON)		12,327	5,659	13,275	7,516
TOTAL FINANCIAL COST		25,422	14,179	13,307	9,893
NET BENEFIT	ANNUAL			12,115	4,286
	/UNIT			1.46 /KWH	0.91 /KWH
TOTAL ECONOMIC COST		19,865	11,892	20,969	14,761
NET BENEFIT	ANNUAL			(1,104)	(2,869)
	/UNIT			(0.13)/KWH	(0.61)/KWH
TOTAL FINANCIAL COST ELECTRIC				3,509	2,975
GROSS BENEFIT (FIN)	ANNUAL			21,913	11,205
	/UNIT			2.64 /KWH	2.39 /KWH
TOTAL ECONOMIC COST ELECTRIC				2,990	2,540
GROSS BENEFIT (ECON)	ANNUAL			16,875	9,351
	/UNIT			2.03 /KWH	1.79 /KWH

NOTES:
(1) Assumes that well cost is independant of pumpset type.
(2) Connection cost of Rs 40250, bribe of 10,000 plus wiring of 500.
(3) Includes fuel surcharge of Rs 0.22/kwh.
(4) Includes distribution losses, area distribution charges and RE O&M costs.

* Note: The economic cost for electricity used in this table is a preliminary estimate which indicates an approximate break-even cost between diesel and electricity under the typical example. Later estimates of the economic cost of electricity are higher. See Table 3.4-1 and related text for these results.

APPENDIX F
ESTIMATION OF RURAL INDUSTRY BENEFITS AND COSTS

Appendix F

Estimation of Rural Industry Benefits and Costs

1. General Description of Small Industrial Users

As used in these illustrative cases, a small rural industrial user of electricity has a 12 hp motor for multiple uses. In computing the benefits of using electricity, it is compared to the use of a similar sized diesel engine, for the same uses.

The alternatives are summarized in Table F-1., are for electric prime movers as compared with diesel, used for totals of 1,000 and 2,000 hours per year. They are assumed to deliver power at the same transmission efficiencies, since both are transmitting the power through a belt drive. There are large differences, however, in the efficiencies at which the motor and engine convert electricity and diesel fuel into motion, respectively: the electric motor, in the typical case, converts at 17.5% efficiency, while the engine converts at 70%.

Four cases are presented for both electric and diesel prime movers in the tables in this appendix:

(1) a typical case, where both diesel and electric systems are operated at customary efficiencies, both diesel and electric systems use belt drives;

(2) a more favorable, "possible" case, where both electric and diesel prime movers increase their system efficiencies through improved operations, both electric prime mover and diesel use belt drives;

(3) same as case (1), except that the electric prime mover uses direct drive;

(4) same as case (2), except that the electric prime mover uses direct drive.

In the "possible" cases, the transmission and engine/motor efficiences are increased to reflect improved equipment matching, operations procedures, and maintenance. This cost reduction is also reflected in the reduced O&M costs for diesel engines.

For all cases, the end-use requirements and rated horsepower are the same. The pre-transmission power required is computed as the end-use requirements divided by the transmission efficiency. This pre-transmission power

requirement is then divided by the motor or engine efficiency to calculate the fuel/electricity requirements.

2. Computation Methods

The economic capital costs are computed as follows:

Foreign Exchange	=	prime mover cost * foreign exchange fraction * foreign exchange shadow price
Duty	=	prime mover cost * foreign exchange fraction * duty rate
Unskilled Labor	=	(prime mover cost - foreign exchange - duty) * .75 * unskilled labor shadow price
Skilled Labor	=	(prime mover cost - foreign exchange - duty) * .25
Total Economic Capital Cost	=	Foreign exchange + unskilled labor + skilled labor

The economic capital costs for the prime mover and connection were annualized and computed separately, due to their differing life spans. These computations are not shown on the tables. The connection charges are Rs 6,000 for a transformer (estimated at Rs 500 per kVA for a 12 kVA unit), Rs 4,000 for the service drop, Rs 5,000 for 10 m of LT line at Rs 500/m, and Rs 10,000 of unofficial charges.

The method of computing operation and maintenance costs is the same as for agricultural users (see Appendix E).

Energy consumption rate is computed as the pre-transmission power requirement divided by the engine or motor efficiency. For the diesel unit, this is then converted into MJ. The fuel consumption rate is based on the energy content of the fuel, given in the tables. Total fuel or electricity consumed is computed as the fuel or electricity consumption rate multiplied by the number of hours of operation.

The financial cost of electricity is based on the B-1 tariff schedule:

Capacity Charge: Rs 28/kW * HP rating of motor / kWh used
Energy Charge: Rs .80/kWh
Fuel Adjustment Surcharge: Rs .22/kWh

The fuel adjustment surcharge is based on an average from July, 1986, to June, 1987.

3. Interpretation of Results

In the computation of net benefits in Tables .] and .], the costs of diesel are viewed as avoided costs when using electricity and are therefore benefits of using electricity. Financially, electricity shows an annual advantage over diesel for the user of almost Rs 9,000, or Rs .70 per kWh, when comparing the typical cases. This advantage is substantially reduced when comparing the "possible" cases, due mostly to the greater potential improvement in diesel engine efficiencies, and in opportunites for O&M improvements.

The economic comparison shows a marginal benefit of diesel over electricity for the typical case, and a somewhat larger benefit for diesel in the "possible" case. From society's point of view, diesel prime movers are slightly prefered to electricity, if the existing belt-driven system is replaced with a belt-driven electric prime mover.

There are greater advantages to the user to replace the diesel system with an direct-drive electric prime mover, as shown in table ▼]. The financial benefits are clear, at Rs 11,031 or 1.02 per kWh for the typical case, and Rs .45 in the possible case. From the economic point of view, this advantage is less obvious. The net benefits are still positive for the typical case, but are somewhat negative in the "possible" case.

The conclusion from this illustrative set of cases are

(1) It is most advantageous, from both the user's and society's perspective, to substitute a belt-driven diesel prime mover with a direct-drive electric motor.

(2) If the diesel system has already been optimized for efficiency, operation, and maintenance, there is a slight disadvantage to this substitution.

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FINANCIAL/ECONOMIC ANALYSIS OF INDUSTRIAL PRIME MOVER COSTS
CASE #1: High Speed diesel vs. Electric - New Installation

22-Jun-88
05:50 PM

(All prices in Pak. Rs)		HSD Typical	HSD Possible	ELECTRIC Typical	ELECTRIC Possible
End Use Power Requirement		9.6 hp	9.6 hp	9.6 hp	9.6 hp
Transmission Efficiency =		80.0%	85.0%	80.0%	85.0%
Shaft Power Req'd		12.0	11.3	12.0	11.3
Motor/Engine Efficiency =		17.5%	25.0%	70.0%	80.0%
Overall Efficiency		14.0%	21.3%	56.0%	68.0%
Engine/Motor size =		12 hp	12 hp	12 hp	12 hp
Utilization (Hrs/yr)		1,000 hrs	1,000 hrs	1,000 hrs	1,000 hrs
Utilization rate (%)		11.4%	11.4%	11.4%	11.4%
CAPITAL COST:					
Diesel engine life =	7 yrs			Motor life = 8 yrs	
Discount Rate (ECON) =	10.0%			Connection = 30 yrs	
Discount Rate (FIN) =	15.0%				
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content	-> FE%			FE%	
Prime Mover Cost	40%	8,124	8,124	35% 7,632	7,632
Import duties (Included)		20.00%	20.00%	20.00%	20.00%
Connection Cost		--	--	20% 25,000	25,000
Annualized Cap Cost (FIN)		1,953	1,953	5,508	5,508
Annualized Cap Cost (ECON)		1,492	1,492	2,756	2,756
OPERATION AND MAINTENANCE:					
Labor Shadow Price factor =		0.9			
Forgn. Exch. shadow price factor =		1.0			
Foreign exch. content	-> FE%			FE%	
Labor (unskilled)		3.50 /hr	3.50 /hr	0.50 /hr	0.50 /hr
Lube oil (Cost/hr)	90%	5.74 /hr	3.78 /hr	--	--
Other O&M/hr	5%	0.75 /hr	0.75 /hr	5% 0.61 /hr	0.61 /hr
Annual O&M cost (FIN)		9,994	8,034	1,109	1,109
Annual O&M cost (ECON)		6,584	5,666	1,022	1,022
ENERGY COST:					
High Speed diesel oil - MJ/l		37.4			
Energy Consumption/Hour		134.1 MJ/h	121.3 MJ/h	17.1 hph/h	14.1 hph/h
Fuel(Energy) Consumption/hr		4.92 l/h	3.24 l/h	12.8 KWH/H	10.5 KWH/H
Total Fuel(Energy)/yr		4,923 l	3,244 l	12,789 KWH	10,532 KWH
Financial Cost/unit		4.00 /l	4.00 /l	1.26 /KWH	1.29 /KWH
Economic Cost/unit		3.25 /l	3.25 /l	1.60 /KWH	1.60 /KWH
Annual Energy Cost (FIN)		19,694	12,975	16,052	13,573
Annual Energy Cost (ECON)		16,001	10,542	20,462	16,851
TOTAL FINANCIAL COST		31,641	22,962	22,670	20,191
NET BENEFIT/COST	ANNUAL			8,971	2,771
	/UNIT			0.70 /KWH	0.26 /KWH
TOTAL ECONOMIC COST	-	24,077	17,700	24,240	20,629
NET BENEFIT/COST	ANNUAL			(163)	(2,930)
	/UNIT			(0.01) /KWH	(0.28) /KWH
TOTAL FINANCIAL COST ELECTRIC				2,810	2,810
GROSS BENEFIT/COST (FIN)	ANNUAL			28,831	20,152
	/UNIT			2.25 /KWH	1.91 /KWH
TOTAL ECONOMIC COST ELECTRIC				2,311	2,311
GROSS BENEFIT/COST (ECON)	ANNUAL			21,766	15,388
	/UNIT			1.70 /KWH	1.20 /KWH

APPENDIX G
VILLAGE RURAL ELECTRIFICATION MODEL

Appendix G

Village Rural Electrification Model

The village used in the illustrative analysis consists of 300 households, of which 90 are low income, 180 are middle income, and 30 are high income. There are 30 tubewells, 3 small industries, and 30 commercial establishments and community connections. The village is 3 km from the nearest 11kV line, and the average length of LT line required per customer is 7 m.

A number of assumptions were made concerning the penetration rates for each customer class. These are shown in the table below:

User Type	Maximum Penetration	Year of Max Pene.	kWh/ Year	Tariff Class
Households				
Low Income	50%	5	240	A-1
Mid Income	75%	5	540	A-1
High Income	75%	5	1800	A-1
Farmers (Tubewells)	40%	6	8300	D
Rural Industry	67%	5	12800	B-1
Commercial/ Community	75%	5	500	A-2

It was further assumed, for these analyses, that the totals for these customer types did not increase over time.

On the basis of statistics related to Sind (ref), almost 80% of the settlements, and 40% of the rural population are in settlements with populations of less than 200. A sensitivity analysis was therefore conducted to determine the relationship between village size and the economic viability of RE. The results of this analysis are illustrated on the following figure.

While this analysis was carried out with illustrative data only, it does serve to demontrate that there is an apparent threshhold of population below which the ecomonic destrablility of RE drops precipitously. On the accompanying figure, this threshhold is at about 50 households. Since the establishment of this threshhold will effect the electrification of a large number of rural households, its determination should only follow a careful and detailed analysis using statistically meaningful data.

In order to determine which of the village or settlement characteristics are important in a statistical sense, 57 test cases were run. In each case, different inputs were used to reflect (1) differing distributions of income among households; (2) differing numbers of tubewells, rural industries, and commercial customers; (3) distance of the village from the nearest 11kV line; and (4) population density of the village, as reflected in the average length of LT line length per customer. The net economic benefits per kWh were used as the measure of economic viability of electrifying the village.

When these 57 cases were completed, the results were used in a step-wise multiple regression analysis to determine which of the inputs have the most influence on the economic benefits.

The results of this analysis were that (1) if only small industries in villages are counted, roughly 50% of the variation in net benefits among villages can be captured (the number of small industries was in fact the best "predictor" of net benefits of all the inputs); (2) if both the number of small industries and tubewells are counted, about 77% of the variation in net benefits can be captured; and (3) by counting the numbers of small industries and tubewells, and determining the income distributions, fully 90% of the differences in net benefits among villages can be captured.

This demonstrates that, for a first attempt at measuring net benefits, only three parameters of a village need to be known: the numbers of small industries, numbers of tubewells, and the total population, and preliminary estimates may be based on only the numbers of small industries and tubewells.

The analysis is clouded by the fact that all customer types have negative economic net benefits. To make more accurate and meaningful estimates of economic costs and benefits, further analysis should center around the distributions of costs between fixed and recurrent shares, and the distributions of benefits among the various user groups. This will allow, among other things, for the weighting of benefits to specific income groups in order to introduce equity as a criterion of village selection for electrification.

TYPE OF ANALYSIS: ECONOMIC Date: 22-Jun Page 1: INPUTS
Location: Punjab Time: 17:47

VILLAGE DEMOGRAPHICS:

Total Number of Households: 200
Pumps/Household:
Commercial-Ind/Household:

User Types	Benefit Type	Wgts.	Cons Srpls Ftr	Pct of all Hshld	Num. Cust.	Gr/Y	User Class Penetration Levels (by year) 1	2	3	4	5	6	7	8	9	10
1 LOW INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	30%	90	0.0%	38%	75%	75%	75%	75%	75%	75%	75%	75%	75%
2 AVE INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	60%	180	0.0%	38%	75%	75%	75%	75%	75%	75%	75%	75%	75%
3 HIGH INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	10%	30	0.0%	38%	75%	75%	75%	75%	75%	75%	75%	75%	75%
4 TUBEWELLS	PUMPING	1	1	2%	6	0.0%	8%	17%	25%	33%	42%	50%	50%	50%	50%	50%
5 RURAL INDUSTRY	SHAFT POWER	1	1	1%	3	0.0%	33%	67%	67%	67%	67%	67%	67%	67%	67%	67%
6 COMMERCIAL	LIGHTING + FANS	1	1	7%	21	0.0%	40%	75%	75%	75%	75%	75%	75%	75%	75%	75%
7 OTHER	OTHER	1	1	0%	0	0.0%	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%

User Types	Gross Benefits Per Customer	Peak kW	kwh/y	Conn. Factor	Customer Costs: Rs Conn. Chrg.*	Rs Intr Wrg	Rs Init. Cost	Aver. Tariff Rs/kwh	Per kW Chrg.	FAS	Supply Side Costs: Rs Conn. Chrg.*	Rs Intr Wrg
1 LOW INCOME HOUSEHOLD	525	0.17	240	0.65	1200	250	500	0.39	0		1200	0
2 AVE INCOME HOUSEHOLD	990	0.76	540	0.65	1200	500	750	0.39	0		1200	0
3 HIGH INCOME HOUSEHOLD	2880	1.00	1800	0.65	1200	1000	1000	0.42	0		1200	0
4 TUBEWELLS	16800	8.30	8300	0.65	10250	500	10000	0.29	24	0.22	40250	0
5 RURAL INDUSTRY	21760	12.8	12800	0.65	15000	500	10000	0.60	28	*	9000	0
6 COMMERCIAL	1264	0.76	540	0.65	1200	500	500	1.28	0	*	1200	0
7 OTHER	0	0	0	0	0	0	0	0	0	*	0	0

User Types	Max. Penetr. Levels
1 LOW INCOME HOUSEHOLD	75%
2 AVE INCOME HOUSEHOLD	75%
3 HIGH INCOME HOUSEHOLD	75%
4 TUBEWELLS	50%
5 RURAL INDUSTRY	67%
6 COMMERCIAL/COMMUNITY	75%
7 OTHER	75%

For Sensitivity Analysis:
Percentage of Maximum
Penetration Achieved:
100%

ELECTRIC SUPPLY COST INPUTS:

Cost Change Factor: 0.70 * Discount Rate: 10%
Power Factor : 0.8 (for village & grid subst transformers)

Economic Life of Connections and Wiring: 20 Years
O&M Percentage of Customer Capital Costs: * 5%

Village Distribution:
LT & 11 kv * : 70000 Rs/km
Line Length/Customer : 7 meters
Transformers * : 500 Rs/kva
O&M Costs * : 5% of K costs

Area Distribution:
Distance of 11kV Line : 3 km
Cost of 11 kv Line * : 99000 Rs
Grid Substation Cost* : 1000 Rs/kva
RE Transmission * : 0 Rs/kva
O&M Costs * : 5% of K cost

Generation and Transmission Costs:
G+T Capac Charge : 30000 Rs/kW
Energy Charge : 0.554 Rs/kWh
Enrgy Chrge Growth Rte : 0%
Distribution Losses : 9%

(*) Denotes Inputs to which the Cost Change Factor is applied

USER TYPE: 1 LOW INCOME HOUSEHOLD 22-Jun Page 2.
BENEFIT TYPE: LIGHTING + APPLIANCES 17:47

Per User-Year

Gross Benefits or Savings	525	1 Rs/y
Electricity Use	240	1 kwh/y
Savings/kWh	2.19 Rs/kwh	(implicit calculation and used in calculating total kwh used)
Peak Load	0.17 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
User Benefits	1 Rs/y	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525
User # Growth Rate/yr:		0%																		
Number of Potential Users:		90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
% Connected:		38%	75%	75%	75%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:		33	34	0	0	0	0	0	0	0	0									
Total Connections (cumulative)		33	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67	67

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	17	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Total kWh	kWh	8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Coincident kW-peak	kW	4	7	7	7	7	7	7	7	7	7									1

USER TYPE: 2 AVE INCOME HOUSEHOLD 22-Jun Page 2.
BENEFIT TYPE: LIGHTING + APPLIANCES 17:47

Per User-Year

Gross Benefits or Savings	990	1 Rs/y
Electricity Use	540	1 kwh/y
Peak Load	0.36 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
User Benefits	1 Rs/y	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990
User # Growth Rate/yr:		0%																		
Number of Potential Users:		180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
% Connected:		38%	75%	75%	75%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:		67	68	0	0	0	0	0	0	0	0									
Total Connection (cumulative)		67	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	66	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Total kWh	kWh	36	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Coincident kW-peak	kW	16	32	32	32	32	32	32	32	32	32									1

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USER TYPE: 3 HIGH INCOME HOUSEHOLD 22-Jun Page 3.
BENEFIT TYPE: LIGHTING + APPLIANCES 17:47

Per User-Year

Gross Benefits or Savings	2880	1 Rs/y
Electricity Use	1800	1 kwh/y
Peak Load	1.00 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
User Benefits 1 Rs/y	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880	2880
User # Growth Rate/Yr:	0%																			
Number of Potential Users:	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
% Connected:	38%	75%	75%	75%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	11	11	0	0	0	0	0	0	0	0										
Total Connection (cumulative)	11	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	32	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
Total kWh	kWh	20	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Coincident kW-peak	kW	7	14	14	14	14	14	14	14	14	14									1	14

USER TYPE: 4 TUBEWELLS 22-Jun Page 3.
BENEFIT TYPE: PUMPING 17:47

Per User-Year

Gross Benefits or Savings	16.80	1000 Rs/y
Electricity Use	8.30	1000 kwh/y
Peak Load	8.30 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
User Benefits 1000 Rs/y	17	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8	16.8
User # Growth Rate/Yr:	0%																			
Number of Potential Users:	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
% Connected:	6%	17%	25%	33%	42%	50%	50%	50%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	0	1	0	1	0	1	0	0	0	0										
Total Connection (cumulative)	0	1	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

USER CLASS BENEFITS AND ELECTRICITY USE (1 + 1000)

Benefits	Rs/y	0	17	17	34	34	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total kWh	kWh	0	8	8	17	17	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Coincident kW-peak	kW	0	5	5	11	11	16	16	16	16	16									1	16

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USER TYPE: 5 RURAL INDUSTRY 22-Jun Page 4.
BENEFIT TYPE: SHAFT POWER 17:47

Per User-Year

Gross Benefits or Savings	21.8	1000 Rs/y
Electricity Use	12.8	1000 kwh/y
Peak Load	12.80	kw
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	2
User Benefits 1000 Rs/y	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	2
User # Growth Rate/Yr:	0%																			
Number of Potential Users:	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	
% Connected:	33%	67%	67%	67%	67%	67%	67%	67%	67%	67%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
# New Connections:	1	1	0	0	0	0	0	0	0	0										
Total Connection (cumulative)	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	

USER CLASS BENEFITS AND ELECTRICITY USE (1 * 1000)

Benefits	Rs/y	22	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44		4
Total kWh	kWh	13	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26		2
Coincident kW-peak	kW	0	17	17	17	17	17	17	17	17	17										(	1

USER TYPE: 6 COMMERCIAL 22-Jun Page 4.
BENEFIT TYPE: LIGHTING + FANS 17:47

Per User-Year

Gross Benefits or Savings	1.26	1000 Rs/y
Electricity Use	0.54	1000 kwh/y
Peak Load	0.36	kw
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	2
User Benefits 1000 Rs/y	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
User # Growth Rate/Yr:	0%																			
Number of Potential Users:	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	21	2
% Connected:	40%	75%	75%	75%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%	
# New Connections:	8	7	0	0	0	0	0	0	0	0										
Total Connection (cumulative)	8	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	1

USER CLASS BENEFITS AND ELECTRICITY USE (1 * 1000)

Benefits	Rs/y	10	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
Total kWh	kWh	4	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8		
Coincident kW-peak	kW	2	4	4	4	4	4	4	4	4	4											

Per User-Year

Gross Benefits or Savings	0.0	1 Rs/y
Electricity Use	0.0	1 kWh/y
Peak Load	0.00 kW	
Coincidence Factor	0.00	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
User Benefits 1 Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
User # Growth Rate/Yr:	0%																			
Number of Potential Users:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Connected:	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	0	0	0	0	0	0	0	0	0	0										
Total Connection (cumulative)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

USER CLASS BENEFITS AND ELECTRICITY USE

Benefits	Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total kWh	kWh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coincident kW-peak	kW	0	0	0	0	0	0	0	0	0	0									0	0

SUMMARY OF BENEFITS (with weights) Page 6. Date: 22-Jun
Time: 17:47

Type of Analysis: ECONOMIC

	NPV	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 LOW INCOME HOUSEHOLD		LIGHTING + APPLIANCES				(1000)																
Benefits		Rs/y	17	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Weighted	283		17	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Total kWh		kWh	8	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16
Coincident Pk/Load Fact.		kW	4	7	7	7	7	7	7	7	7	7	Load Factor in Year 10: 24.8%									
Tariff Payments		Rs	7	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Connection Costs		Rs	40	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	17	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	67	73	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Total Connections (cumulative)												67										67
2 AVE INCOME HOUSEHOLD		LIGHTING + APPLIANCES				(1000)																
Benefits		Rs/y	66	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Weighted	1077		66	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Total kWh		kWh	36	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Coincident kW-peak		kW	16	32	32	32	32	32	32	32	32	32	Load Factor in Year 10: 26.3%									
Tariff Payments		Rs	14	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Connection Costs		Rs	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial Costs		Rs	50	51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	74	74	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	178	195	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Total Connections (cumulative)												135										135
3 HIGH INCOME HOUSEHOLD		LIGHTING + APPLIANCES				(1000)																
Benefits		Rs/y	32	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
Weighted	511		32	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
Total kWh		kWh	20	40	40	40	40	40	40	40	40	40	40	40	40.	40	40	40	40	40	40	40
Coincident kW-peak		kW	7	14	14	14	14	14	14	14	14	14	Load Factor in Year 10: 31.6%									
Tariff Payments		Rs	8	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Connection Costs		Rs	13	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	43	52	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Total Connections (cumulative)												22										22

SUMMARY OF BENEFITS (Continued) Page 7. Date: 22-Jun Time: 17:47

4 TUBEWELLS		PUMPING				(1000)															
Benefits		Rs/y	0	17	17	34	34	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Weighted	308		0	17	17	34	34	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total kWh		kWh	0	8	8	17	17	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Coincident kW-peak		kW	0	5	5	11	11	16	16	16	16	16	Load Factor in Year 10:					17.6%			(
Tariff Payments		Rs	0	4	4	8	8	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Connection Costs		Rs	0	10	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	0	10	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	0	25	4	29	8	33	13	13	13	13	13	13	13	13	13	13	13	13	13
Total Connections (cumulative)												3									
5 RURAL INDUSTRY		SHAFT POWER				(1000)															
Benefits		Rs/y	22	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Weighted	351		22	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44	44
Total kWh		kWh	13	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Coincident kW-peak		kW	0	17	17	17	17	17	17	17	17	17	Load Factor in Year 10:					17.6%			(
Tariff Payments		Rs	13	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Connection Costs		Rs	15	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	39	52	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26
Total Connections (cumulative)												2									
6 COMMERCIAL		LIGHTING - FANS				(1000)															
Benefits		Rs/y	10	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Weighted	153		10	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
Total kWh		kWh	4	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1
Coincident kW-peak		kW	2	4	4	4	4	4	4	4	4	4	Load Factor in Year 10:					26.5%			(
Tariff Payments		Rs	6	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Connection Costs		Rs	10	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	24	28	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Connection (cumulative)												15									
7 OTHER		OTHER				(1)															
Benefits		Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weighted			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total kWh		kWh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coincident kW-peak		kW	0	0	0	0	0	0	0	0	0	0	Load Factor in Year 10:					0.0%			(
Tariff Payments		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Connection Costs		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Connection (cumulative)												0									
TOTALS																					
Benefits	1000	Rs/y	147	311	311	328	328	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Weighted			147	311	311	328	328	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Total kWh	1000	kWh	81	171	171	179	179	187	187	187	187	187	187	187	187	187	187	187	187	187	187
Coincident Pk/Load Fact.		kW	28	79	79	84	84	90	90	90	90	90									
			Load Factor in Year 10:									23.8%									
Tariff Payments	799	Rs	45	94	94	98	98	102	102	102	102	102	102	102	102	102	102	102	102	102	102
Connection Costs	207	Rs	110	118	0	7	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial Costs	181	Rs	92	103	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring	101	Rs	57	58	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments		Rs	247	315	94	115	98	119	102	102	102	102	102	102	102	102	102	102	102	102	102
Total Connections (cumulative)												244									

NPV of kWh at 10% -- 1460 x 1000 kWh

ELECTRICITY SUPPLY COSTS Page 6. 17:47 22-Jun
Cost Change Factor: 0.70 Discount Rate: 10%
Power Factor: 0.8 Type of Analysis: ECONOMIC
Peak Demand (kw): 89.62 at gen 103.4 at grid (75% diversity factor)

YEAR

		Rs @	Life	NPV	Cost Factor	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CUSTOMER AND CONNECTION COSTS							1000 Rs.												
LOW INCOME HOUSEHOLD	Intrnl	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	48	0.7	2.9	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
AVE INCOME HOUSEHOLD	Intrnl	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	97	0.7	6.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
HIGH INCOME HOUSEHOLD	Intrnl	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	16	0.7	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
TUBEWELLS	Intrnl	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	40250	30	55	0.7	0.0	3.0	3.0	6.0	6.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0	9.0
RURAL INDUSTRY	Intrnl	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	9000	30	11	0.7	0.7	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
COMMERCIAL	Intrn.	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	11	0.7	0.7	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
OTHER	Intrn.	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	0	30	0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Intrnl Costs	Rs					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Conn. Costs	Rs					11.3	25.6	25.6	28.6	28.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
Total Capital Costs	Rs		30	237		11.3	25.6	25.6	28.6	28.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6	31.6
O&M Costs	Rs	5%	of K cst	112		5.3	12.1	12.1	13.5	13.5	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9
TOTAL CUSTOMER COSTS	Rs			349		16.6	38	38	42	42	46	46	46	46	46	46	46	46	46
Average	Rs/kwh			0.24		0.20	0.22	0.22	0.24	0.24	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fixed Share	Rs/kw			0.16		0.14	0.15	0.15	0.16	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Recurrent Sh	Rs/kw			0.08		0.07	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
** Pk-kw=	90 in year 10 less ag			16	kw PUMPING														
VILLAGE DISTRIBUTION							1000 Rs.												
LT & 11 kv	Rs/km	70000	30	75	0.7	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
No. of Non- PUMPIN Customers:		241																	
Line Length/Customer:		7 meters																	
Transformers	Rs/kva	500	30	38	0.7	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
KW of Non- PUMPIN Customers:		73 at gen		96 at village (85% diversity factor)															
O&M Costs	Rs	5% of K costs		53		6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2	6.2
Total Village Costs	Rs			166		19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Average	Rs/kwh			0.11		0.24	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Fixed Share	Rs/kw			0.08		0.16	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Recurrent Sh	Rs/kw			0.04		0.08	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
AREA DISTRIBUTION		** Distance:		3 km.			1000 Rs												
11 kv Line	Rs	99000	30	188	0.7	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Transm+Substat	Rs/kva	1000	30	82	0.7	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
O&M Costs	Rs	5%	of K cst	127		14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.9
Total Area Costs	Rs			396		46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6	46.6
Average	Rs/kwh			0.27		0.57	0.27	0.27	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Fixed Share	Rs/kw			0.18		0.39	0.19	0.19	0.18	0.18	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Recurrent Sh	Rs/kw			0.09		0.18	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
GENERATION AND TRANSMISSION COSTS																			
** Pk-kw=	89.62 in year 10						1000 Rs.												
G+T Capac Char	Rs/kW	30000	30	2174		90	251	251	268	268	285	285	285	285	285	285	285	285	285
Fixed Share	Rs/kw			1.49		1.11	1.47	1.47	1.50	1.50	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52
Unit G&T Cost	Rs/kwh	0.554	6%			0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
w/Dst Losses		9% losses		0.61		0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
TTL Gen/Trans	Rs			3063		140	355	355	377	377	399	399	399	399	399	399	399	399	399
Average	Rs/kwh			2.10		1.72	2.08	2.08	2.11	2.11	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13	2.13
							1000 Rs.												
TOTAL COSTS	Rs			3975		222	458	458	465	465	512	512	512	512	512	512	512	512	512
Ave Unit Cost	Rs/kwh			2.72		2.74	2.69	2.69	2.71	2.71	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Fixed Share	Rs/kw			1.91		1.81	1.88	1.88	1.91	1.91	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93	1.93
Recurrent Sh	Rs/kw			0.81		0.94	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80

Date: 22-Jun-88 Page 9.
Time: 05:47 PM Type of Analysis: ECONOMIC

NET PRESENT VALUE CALCULATIONS:

	NPV		Year: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Wtd Wgtd Benefits	2683	1000 Rs/y	147	311	311	328	328	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Unwtd Benefits	2683	1000 Rs/y	147	311	311	328	328	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
Total Supply Costs	3975	1000 Rs/y	222	458	458	485	485	512	512	512	512	512	512	512	512	512	512	512	512	512	512	512
2.72		Rs/kwh	2.74	2.69	2.69	2.71	2.71	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73	2.73
Internal Wiring	99	0.067	6	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Customer Pymts	1279	1000 Rs/y	73	151	151	157	157	163	163	163	163	163	163	163	163	163	163	163	163	163	163	163
0.88		Rs/kwh	0.90	0.88	0.88	0.88	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
Payments to Utility	1003	1000 Rs/y	57	118	118	123	123	128	128	128	128	128	128	128	128	128	128	128	128	128	128	128
0.69		Rs/kwh	0.70	0.69	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
INCREMENTAL INCOME FLOWS:																						
Net Weighted Benefits			-81	-157	-157	-169	-169	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179
-0.75	NPV:	-1391	1000 Rs.																			
Net Unweighted Benefits			-81	-157	-157	-169	-169	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179	-179
-0.75	NPV:	-1391	1000 Rs.																			

TYPE OF ANALYSIS: FINANCIAL Date: 10-Jun- Page 1: INPUTS
Location: Punjab Time: 00:24

VILLAGE DEMOGRAPHICS:

Total Number of Households: 770
Pumps/Household:
Commercial-Ind/Household:

User Types	Benefit Type	Cons Srpls Agts.	Cons Srpls Ftr	Fct of all Hshld	Hum. Cust.	Gr/Y	User Class Penetration Levels (by year) 1	2	3	4	5	6	7	8	9	10
1 LOW INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	30%	90	0.0%	10%	20%	30%	40%	50%	50%	50%	50%	50%	50%
2 AVE INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	60%	180	0.0%	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%
3 HIGH INCOME HOUSEHOLD	LIGHTING + APPLIANCES	1	1	10%	30	0.0%	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%
4 TUBEWELLS	PUMPING	1	1	2%	6	0.0%	8%	17%	25%	33%	42%	50%	50%	50%	50%	50%
5 RURAL INDUSTRY	SHAFT POWER	1	1	1%	3	0.0%	13%	27%	40%	54%	67%	67%	67%	67%	67%	67%
6 COMMERCIAL	LIGHTING + FANS	1	1	7%	21	0.0%	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%
7 OTHER	OTHER	1	1	0%	0	0.0%	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%

User Types	Gross Benefits Per Customer	Peak kW	kWh/y	Coin. Factor	Customer Costs: Rs Conn. Chrg.*	Rs Intr Wrg	Rs Init. Cost	Aver. Tariff Rs/kWh	Per kW Chrg.	FAS	Supply Side Costs: Rs Conn. Chrg.*	Rs Intr Wrg
1 LOW INCOME HOUSEHOLD	525	0.17	240	0.65	1200	250	500	0.39	0		1200	0
2 AVE INCOME HOUSEHOLD	990	0.36	540	0.65	1200	500	750	0.39	0		1200	0
3 HIGH INCOME HOUSEHOLD	2689	1.00	1800	0.65	1200	1000	1000	0.42	0		1200	0
4 TUBEWELLS	21600	8.30	8300	0.65	10250	500	10000	0.29	24	0.22	40250	0
5 RURAL INDUSTRY	28800	12.8	12800	0.65	15000	500	10000	0.80	28	*	9000	0
6 COMMERCIAL	1264	0.36	540	0.65	1200	500	500	1.28	0	*	1200	0
7 OTHER	0	0	0	0	0	0	0	0	0	*	0	0

User Types	Max. Penetr. Levels
1 LOW INCOME HOUSEHOLD	50%
2 AVE INCOME HOUSEHOLD	75%
3 HIGH INCOME HOUSEHOLD	75%
4 TUBEWELLS	50%
5 RURAL INDUSTRY	67%
6 COMMERCIAL/COMMUNITY	75%
7 OTHER	75%

For Sensitivity Analysis:
Percentage of Maximum
Penetration Achieved:
100%

ELECTRIC UTILITY COST INPUTS:

Cost Change Factor: 1.00 * Discount Rate: 15%
Power Factor : 0.8 (for village & grid subst transformers)

Economic Life of Connections and Wiring: 20 Years
O&M Percentage of Customer Capital Costs: * 5%

Village Distribution:
LT & 11 kv * : 70000 Rs/km
Line Length/Customer : 7 meters
Transformers * : 500 Rs/kva
O&M Costs * : 5% of K costs

Area Distribution:
Distance of 11kV Line : 3 km
Cost of 11 kv Line * : 99000 Rs
Grid Substation Cost* : 1000 Rs/kva
RE Transmission * : 0 Rs/kva
O&M Costs * : 5% of K cost

Generation and Transmission Costs:
G+T Capac Charge : 5200 Rs/kW
Energy Charge : 0.223 Rs/kWh
Energy Chrge Growth Rte : 0%
Distribution Losses : 9%

(*) Denotes Inputs to which the Cost Change Factor is applied

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USER TYPE: 1 LOW INCOME HOUSEHOLD 10-Jun Page 2.
BENEFIT TYPE: LIGHTING + APPLIANCES 00:24

Per User-Year

Gross Benefits or Savings	525	1 Rs/y
Electricity Use	240	1 kwh/y

Savings/kW: 2.19 Rs/kwh (implicit calculation and used in calculating total kWh used)
Peak Load 0.17 kW
Coincidence Factor 0.65

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
User Benefits 1 Rs/y	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525
User # Growth Rate/yr:	0%																		
Number of Potential Users:	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90	90
% Connected:	10%	20%	30%	40%	50%	50%	50%	50%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	9	9	9	9	9	0	0	0	0	0									
Total Connections (cumulative)	9	18	27	36	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	5	9	14	19	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Total kWh	kWh	2	4	6	9	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Coincident kW-peak	kW	1	2	3	4	5	5	5	5	5	5									1

USER TYPE: 2 AVE INCOME HOUSEHOLD 10-Jun Page 2.
BENEFIT TYPE: LIGHTING + APPLIANCES 00:24

Per User-Year

Gross Benefits or Savings	990	1 Rs/y
Electricity Use	540	1 kwh/y
Peak Load	0.36 kW	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
User Benefits 1 Rs/y	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990	990
User # Growth Rate/yr:	0%																		
Number of Potential Users:	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
% Connected:	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	27	27	27	27	27	0	0	0	0	0									
Total Connection (cumulative)	27	54	81	108	135	135	135	135	135	135	135	135	135	135	135	135	135	135	135

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	27	53	80	107	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Total kWh	kWh	15	29	44	58	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Coincident kW-peak	kW	6	13	19	25	32	32	32	32	32	32									1

USER TYPE: 3 HIGH INCOME HOUSEHOLD 10-Jun Page 3.
BENEFIT TYPE: LIGHTING + APPLIANCES 00:24

Per User-Year

Gross Benefits or Savings	2889	1 Rs/y
Electricity Use	1800	1 kwh/y
Peak Load	1.00 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
User Benefits	1 Rs/y	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889	2889

User # Growth Rate/yr:		0%																			
Number of Potential Users:		30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
% Connected:		15%	30%	45%	60%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:		4	5	4	5	4	0	0	0	0	0										
Total Connection (cumulative)		4	9	13	18	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22

USER CLASS BENEFITS AND ELECTRICITY USE (1000 + 1)

Benefits	Rs/y	12	26	38	52	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Total kWh	kWh	7	16	23	32	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Coincident kW-peak	kW	3	6	8	12	14	14	14	14	14	14									1	14

USER TYPE: 4 TUBEWELLS 10-Jun Page 3.
BENEFIT TYPE: PUMPING 00:24

Per User-Year

Gross Benefits or Savings	21.60	1000 Rs/y
Electricity Use	8.30	1000 kwh/y
Peak Load	8.30 kw	
Coincidence Factor	0.65	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
User Benefits	1000 Rs/y	22	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6	21.6

User # Growth Rate/yr:		0%																			
Number of Potential Users:		6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
% Connected:		8%	17%	25%	33%	42%	50%	50%	50%	50%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:		0	1	0	1	0	1	0	0	0	0										
Total Connection (cumulative)		0	1	1	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3

USER CLASS BENEFITS AND ELECTRICITY USE (1 + 1000)

Benefits	Rs/y	0	22	22	43	43	65	65	65	65	65	65	65	65	65	65	65	65	65	65	65
Total kWh	kWh	0	8	8	17	17	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Coincident kW-peak	kW	0	5	5	11	11	16	16	16	16	16									1	16

USER TYPE: 7 OTHER
BENEFIT TYPE: OTHER

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Per User-Year

Gross Benefits or Savings	0.0	1 Rs/y
Electricity Use	0.0	1 kWh/y
Peak Load	0.00 kW	
Coincidence Factor	0.00	

INDIVIDUAL USER BENEFIT TIME PATTERN

Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
User Benefits 1 Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
User # Growth Rate/Yr:	0%																		
Number of Potential Users:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
% Connected:	15%	30%	45%	60%	75%	75%	75%	75%	75%	75%	0%	0%	0%	0%	0%	0%	0%	0%	0%
# New Connections:	0	0	0	0	0	0	0	0	0	0									
Total Connection (cumulative)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

USER CLASS BENEFITS AND ELECTRICITY USE

Benefits	Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total kWh	kWh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coincident kW-peak	kW	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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SUMMARY OF BENEFITS (with weights) Page o. Date: 10-Jun
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Scpls Hum. User Class Penetration Levels (by year)

	Year:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1 LOW INCOME HOUSEHOLD	LIGHTING + APPLIANCES				(1000)																
Benefits	Rs/y	5	9	14	19	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Weighted		5	9	14	19	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Total kWh	kWh	2	4	6	9	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Coincident Pk/Load Fact.	kW	1	2	3	4	5	5	5	5	5	5	Load Factor in Year 10:				24.8%				5	5
Tariff Payments	Rs	1	2	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Connection Costs	Rs	11	11	11	11	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs	Rs	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring	Rs	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments	Rs	18	19	20	21	22	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Total Connections (cumulative)											45										45
2 AVE INCOME HOUSEHOLD	LIGHTING + APPLIANCES				(1000)																
Benefits	Rs/y	27	53	80	107	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
weighted		27	53	80	107	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134	134
Total kWh	kWh	15	29	44	58	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Coincident kW-peak	kW	6	12	19	25	32	32	32	32	32	32	Load Factor in Year 10:				26.3%				1	32
Tariff Payments	Rs	6	11	17	23	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Connection Costs	Rs	32	37	32	32	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial Costs	Rs	20	20	20	20	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring	Rs	14	14	14	14	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments	Rs	72	78	83	89	95	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Total Connections (cumulative)											135										135
3 HIGH INCOME HOUSEHOLD	LIGHTING + APPLIANCES				(1000)																
Benefits	Rs/y	12	26		52	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Weighted		12	26	38	52	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64	64
Total kWh	kWh	7	16	23	32	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Coincident kW-peak	kW	3	6	8	12	14	14	14	14	14	14	Load Factor in Year 10:				31.6%				1	14
Tariff Payments	Rs	3	7	10	14	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Connection Costs	Rs	5	6	5	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inital Costs	Rs	4	5	4	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring	Rs	4	5	4	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments	Rs	16	23	23	30	29	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
Total Connections (cumulative)											22										22

SUMMARY OF BENEFITS (continued) Page 7. Date: 10-Jun
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4 TUBEWELLS	PUMPING				(1000)																
Benefits	Rs/y	0	22	22	43	43	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
Weighted		0	22	22	43	43	65	65	65	65	65	65	65	65	65	65	65	65	65	65	
Total kWh	kWh	0	8	8	17	17	25	25	25	25	25	25	25	25	25	25	25	25	25	25	
Coincident kW-peak	kW	0	5	5	11	11	16	16	16	16	16 Load Factor in Year 10: 17.6%										
Tariff Payments	Rs	0	4	4	8	8	13	13	13	13	13	13	13	13	13	13	13	13	13	13	
Connection Costs	Rs	0	10	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	
Inital Costs	Rs	0	10	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	
Internal Wiring	Rs	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Customer Payments	Rs	0	25	4	29	8	33	13	13	13	13	13	13	13	13	13	13	13	13	13	
Total Connections (cumulative)											3										
5 RURAL INDUSTRY	SHAFT POWER				(1000)																
Benefits	Rs/y	0	29	29	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	
Weighted		0	29	29	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	
Total kWh	kWh	0	13	13	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	
Coincident kW-peak	kW	0	0	8	8	17	17	17	17	17	17 Load Factor in Year 10: 17.6%										
Tariff Payments	Rs	0	13	13	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	
Connection Costs	Rs	0	15	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Inital Costs	Rs	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Internal Wiring	Rs	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Customer Payments	Rs	0	39	13	52	26	26	26	26	26	26	26	26	26	26	26	26	26	26	26	
Total Connections (cumulative)											2										
6 COMMERCIAL	LIGHTING + FANS				(1000)																
Benefits	Rs/y	4	8	11	15	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	
Weighted		4	8	11	15	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	
Total kWh	kWh	2	3.24	4.86	6.48	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	
Coincident kW-peak	kW	1	1	2	3	4	4	4	4	4	4 Load Factor in Year 10: 26.3%										
Tariff Payments	Rs	2	5	7	10	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
Connection Costs	Rs	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Inital Costs	Rs	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Internal Wiring	Rs	2	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Customer Payments	Rs	9	11	14	16	19	12	12	12	12	12	12	12	12	12	12	12	12	12	12	
Total Connection (cumulative)											15										
7 OTHER	OTHER				(1)																
Benefits	Rs/y	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Weighted		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total kWh	kWh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Coincident kW-peak	kW	0	0	0	0	0	0	0	0	0	0 Load Factor in Year 10: 0.0%										
Tariff Payments	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Connection Costs	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Inital Costs	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Internal Wiring	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Customer Payments	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Total Connection (cumulative)											0										
TOTALS																					
Benefits	1000 Rs/y	47	147	194	294	341	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Weighted		47	147	194	294	341	362	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Total kWh	1000 kWh	26	74	100	148	174	182	182	182	182	182	182	182	182	182	182	182	182	182	182	182
Coincident Pk/Load Fact.	kW	11	27	46	63	82	87	87	87	87	87										87
		Load Factor in Year 10:									23.8%										
Tariff Payments	464 Rs	12	42	54	84	96	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Connection Costs	213 Rs	52	78	52	78	52	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Initial Costs	134 Rs	30	51	30	51	30	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Internal Wiring	74 Rs	21	23	21	23	21	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Customer Payments	Rs	94	171	136	213	178	120	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total Connections (cumulative)											222										222

NPV of kWh at 15% — 843 x 1000 kWh

ELECTRICITY SUPPLY COSTS Page 8. (x):24 16-Jun
Cost Change Factor: 1.00 Discount Rate: 15%
Power Factor: 0.8
Peak Demand (kw): 87 at gen 101 at grid

YEAR

		Rs @	Life	NPV	Cost Factor	1000 Rs.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
CUSTOMER AND CONNECTION COSTS																				
LOW INCOME HOUSEHOLD	Intrnl	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	39	1	1.6	3.3	4.9	6.6	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
AVE INCOME HOUSEHOLD	Intrnl	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	117	1	4.9	9.9	14.8	19.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7
HIGH INCOME HOUSEHOLD	Intrnl	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	19	1	0.7	1.6	2.4	3.3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TUBEWELLS	Intrnl	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	40250	30	75	1	0.0	6.1	6.1	12.3	12.3	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4
RURAL INDUSTRY	Intrnl	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	9000	30	13	1	0.0	1.4	1.4	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
COMMERCIAL	Intrn.	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	1200	30	13	1	0.5	1.1	1.6	2.2	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
OTHER	Intrn.	0	30		1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Conn.	0	30	0	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Intrnl Costs	Rs					0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Conn. Costs	Rs					7.9	23.4	31.3	46.8	54.7	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8
Total Capital Costs	Rs		30	276		7.9	23.4	31.3	46.8	54.7	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8	60.8
O&M Costs	Rs	5%	of K cst	91		2.6	7.7	10.3	15.4	17.9	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
TOTAL CUSTOMER COSTS	Rs			366		10.4	31	42	62	73	81	81	81	81	81	81	81	81	81	81
Average	Rs/kwh			0.43		0.41	0.42	0.42	0.42	0.42	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
Fixed Share	Rs/kw			0.33		0.31	0.32	0.31	0.32	0.31	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Recurrent Sh	Rs/kw			0.11		0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
	** Pk-kw=	87 in year 10 less ag		16	kw PUMPING															
VILLAGE DISTRIBUTION						1000 Rs.														
LT & 11 kv	Rs/km	70000	30	102	1	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3	16.3
No. of Non- PUMPIN Customers:		219																		
Line Length/Customer:		7 meters																		
Transformers	Rs/kva	500	30	55	1	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
KW of Non- PUMPIN Customers:		71 at gen	93 at village																	
O&M Costs	Rs	5% of K costs		52		8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Total Village Costs	Rs			209		33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5	33.5
Average	Rs/kwh			0.25		1.31	0.45	0.34	0.23	0.19	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Fixed Share	Rs/kw			0.19		0.99	0.34	0.25	0.17	0.15	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14
Recurrent Sh	Rs/kw			0.06		0.32	0.11	0.08	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
AREA DISTRIBUTION		** Distance:		3 km.		1000 Rs														
11 kv Line	Rs	99000	30	283	1	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2	45.2
Trans+Substati	Rs/kva	1000	30	120	1	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2
O&M Csots	Rs	5%	of K cst	132		21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1	21.1
Total Area Costs	Rs			535		85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5
Average	Rs/kwh			0.63		3.35	1.16	0.86	0.58	0.49	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
Fixed Share	Rs/kw			0.48		2.52	0.87	0.65	0.43	0.37	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Recurrent Sh	Rs/kw			0.16		0.83	0.29	0.21	0.14	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
GENERATION AND TRANSMISSION COSTS																				
	** Pk-kw=	87.19 in year 10				1000 Rs.														
G+T Capac Char	Rs/kW	5200	30	309	1	8	22	37	50	65	69	69	69	69	69	69	69	69	69	69
Fixed Share	Rs/kw			0.37		0.33	0.29	0.37	0.34	0.37	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38
Unit G&T Cost	Rs/kwh	0.223	0%			0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
w/Dst Losses		9% losses		0.25		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
TTL Gen/Trans	Rs			516		15	40	61	86	107	114	114	114	114	114	114	114	114	114	114
Average	Rs/kwh			0.61		0.57	0.54	0.61	0.58	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
						1000 Rs.														
TOTAL COSTS	Rs			1627		144	190	221	267	299	313	313	313	313	313	313	313	313	313	313
Ave Unit Cost	Rs/kwh			1.93		5.64	2.56	2.22	1.80	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Fixed Share	Rs/kw			1.36		4.14	1.82	1.58	1.26	1.20	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21	1.21
Recurrent Sh	Rs/kw			0.57		1.50	0.75	0.64	0.55	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52

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NET PRESENT VALUE CALCULATIONS:

	NPV		Year: 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Wtd Benefits	1669	1000 Rs/y	47	147	194	294	341	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Unwtd Benefits	1669	1000 Rs/y	47	147	194	294	341	362	362	362	362	362	362	362	362	362	362	362	362	362	362
Total Supply Costs	1627	1000 Rs/y	144	190	221	267	299	313	313	313	313	313	313	313	313	313	313	313	313	313	313
1.93		Rs/kwh	5.64	2.56	2.22	1.80	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72	1.72
Internal Wiring	80	0.094	3	7	10	14	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
0.09																					
Total Customer Pymts	916	1000 Rs/y	28	81	109	162	189	197	197	197	197	197	197	197	197	197	197	197	197	197	197
1.09		Rs/kwh	1.08	1.09	1.09	1.09	1.09	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
Payments to Utility	693	1000 Rs/y	20	62	82	123	143	149	149	149	149	149	149	149	149	149	149	149	149	149	149
0.82		Rs/kwh	0.78	0.83	0.82	0.83	0.83	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
Wtd Benefits - Customer Payments			19	66	85	132	151	165	165	165	165	165	165	165	165	165	165	165	165	165	165
0.89	NPV:	754	1000 Rs.																		
Unwtd Benefits - Customer Pay'ts			19	66	85	132	151	165	165	165	165	165	165	165	165	165	165	165	165	165	165
0.89	NPV:	754	1000 Rs.																		
Payments To Utility - Total Cost			-124	-128	-140	-144	-156	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164	-164
-1.11	NPV:	-934	1000 Rs.																		

APPENDIX H
VILLAGE SELECTION CRITERIA. CASE STUDIES

CASE 2 ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

PARAMETERS FOR ECONOMIC ANALYSIS

22-Jun-88

Sr No	DESCRIPTION		HOUSEHOLDS LOW INCOME	HOUSEHOLDS AVG INCOME	HOUSEHOLDS HIGH INCOME	COMMERCIAL + COMMUNITY	SMALL INDUSTRY	TUBEWELLS
A	PRESENT WORTH OF BENEFITS							
	- Gross Benefits/Customer		525	737	1882	700	21760	16800
	- PWB @ DF=10%	Rs	5250	7370	18820	7000	217600	168000
		(Rs 000)	5.25	7.37	18.82	7.00	217.60	168.00
B	PRESENT WORTH OF CAPITAL							
	- Peak kW per Customer at Distribution Transformer		0.22	0.47	1.31	0.39	16.74	10.85
	- Coincident Demand/Customer at Generation Level	kW	0.17	0.36	1.00	0.30	12.80	8.30
	- Captial Cost							
	a. Connection Cost	Rs.	840	840	840	840	6300	28175
	b. Village Distribution Cost @ 1750/kW	Rs.	385	823	2293	683	29295	-
	c. Generation & Transmission Cost @ 0/kW	Rs.	0	0	0	0	0	0
	Sub - Total	Rs.	1225	1663	3133	1523	35595	28175
	- PW of Capital	(Rs 000)	1.84	2.49	4.70	2.28	53.39	42.26
C	PRESENT WORTH OF ENERGY							
	- kWH per Customer		240	540	1800	500	12800	8300
	- Cost of Energy @ Rs 0.60/kWh		144.00	324.00	1080.00	300.00	7680.00	4980.00
	- PW of Energy	(Rs 000)	1.44	3.24	10.80	3.00	76.80	49.80
D	PRESENT WORTH OF COST (Rs 000)		3.28	5.73	15.50	5.28	130.19	92.06

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CASE 2 : ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

TOTAL CAPITAL INVESTMENT, PRESENT WORTH OF COST AND PRESENT WORTH OF BENEFITS

22-Jun-88

Sr No	DESCRIPTION	HOUSE HOLDS LOW INCOME	HOUSE HOLDS AVERAGE INCOME	HOUSE HOLDS HIGH INCOME	HOUSE HOLDS TOTAL	SMALL INDUSTRY	COMMERCIAL + COMMUNITY	TUBEWELLS	11 KV LINE	TOTAL CAPITAL COST (Rs. 000)	TOTAL PW OF COST (Rs 000)	TOTAL PW OF BENEFITS (Rs 000)
A	PER USER (Rs 000)											
a	Capital Investment	1.84	2.49	4.70		53.39	2.28	42.26	56.00			
b	Present Worth of Costs	3.28	5.73	15.50		130.19	5.28	92.06	84.00			
c	Present Worth of Benefits	5.25	7.87	18.82		217.60	7.00	168.00	0.00			
B	PER VILLAGE (No.)											
1	CHAK 012/GD	229	146	19	394	3	47			1142	2521	3691
2	CHAK 011/GD	201	128	17	346	3	41			1022	2263	3322
3	CHAK 013/GD	124	79	10	213	2	26			638	1412	2078
4	CHAK 010/GD	189	121	16	326	3	39			973	2158	3171
5	Jora	329	210	29	568	5	67			1684	3737	5433
6	Miral	332	212	28	572	5	68			1692	3748	5512
7	Kohla	599	383	51	1034	9	123			3058	6774	9943
8	Ottwal Gagar	114	73	10	197	2	24			600	1334	1964
9	CHAK 027/GD	244	155	21	420	3	50			1206	2669	3899
10	CHAK 015/GD	147	94	13	254	2	30			741	1641	2401
11	CHAK 014/GD	339	215	29	582	5	69			1718	3805	5513
12	CHAK 011/1R	220	141	19	380	3	45			1108	2452	3550
13	CHAK 012/1R	246	157	21	424	4	50			1270	2817	4143
14	CHAK 015/1R	275	175	24	474	4	56			1396	3093	4535
15	CHAK 010/1R	244	156	21	421	3	50			1210	2674	3907
16	CHAK 09/1R	212	135	18	365	3	43			1069	2365	3453
C	PER TUBEWELL LOAD CENTRE (3 Tubewells) (Rs 000)									127	276	512

CASE 2b ECONOMIC ANALYSIS TO ELECTRIFY CLUSTERS OF VILLAGES
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES

22-Jun-98

Sr No	CLUSTER No / VILLAGE No	OPTION	FROM	TO	HT LINE Km	CAPITAL COST (RS 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPWB (Rs 000)	BCR	RATIO NPWB : CAPITAL
CLUSTER 1																	
1	1	1	0	1	0.643	36	1142	1178	54	2521	2575	0	3631	3631	1116	1.433	0.947
	11	2	1	11	3.003	168	1718	1886	252	3805	4058	0	5553	5553	1526	1.376	0.809
CLUSTER TOTAL					3.646	204	2859	3064	306	6326	6633	0	9274	9274	2641	1.396	0.862
CLUSTER 2																	
2	12	3	2	12	2.628	147	1108	1255	221	2452	2673	0	3590	3590	917	1.343	0.731
	13	3	12	13	1.449	81	1270	1351	122	2917	2938	0	4143	4143	1204	1.410	0.891
	14	3	12	14	1.609	90	1396	1486	135	3093	3228	0	4535	4535	1307	1.405	0.879
	15	4	13	15	1.984	111	1210	1321	167	2674	2841	0	3907	3907	1066	1.375	0.807
CLUSTER TOTAL					7.669	429	4984	5413	644	11036	11681	0	16175	16175	4494	1.385	0.830
CLUSTER 3																	
3	6	1	0	6	2.543	159	1692	1852	239	3748	3987	0	5502	5502	1516	1.380	0.819
	9	2	6	9	3.003	168	1208	1376	252	2669	2921	0	3999	3999	978	1.335	0.711
	10	2	6	10	2.950	165	741	906	248	1641	1889	0	2401	2401	513	1.271	0.566
CLUSTER TOTAL					8.796	493	3641	4134	739	8057	8796	0	11903	11903	3006	1.342	0.727
CLUSTER 4																	
4	7	1	0	7	6.114	342	3058	3401	514	6774	7288	0	9943	9943	2656	1.364	0.781
CLUSTER 5																	
5	2	2	1	2	2.038	114	1022	1136	171	2263	2434	0	3322	3322	888	1.365	0.781
	3	2	2	3	1.877	105	638	743	158	1412	1570	0	2078	2078	508	1.324	0.684
	4	3	4a	4	0.590	33	973	1006	50	2158	2207	0	3171	3171	964	1.437	0.958
	16	1	3	16	1.555	87	1069	1156	131	2366	2496	0	3468	3468	972	1.389	0.841
CLUSTER TOTAL					6.060	339	3702	4042	509	8199	8708	0	12040	12040	3332	1.383	0.824

CASE 2b : ECONOMIC ANALYSIS TO ELECTRIFY CLUSTERS OF VILLAGES
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES

22-Jun-88

Sr No	CLUSTER No / VILLAGE No	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	CAPITAL COST (RS. 000) VILLAGE/ TUBEWELL	CAPITAL COST (RS. 000) TOTAL	PWC (Rs 000) LINE	PWC (Rs 000) VILLAGE/ TUBEWELL	PWC (Rs 000) TOTAL	PWB (Rs 000) LINE	PWB (Rs 000) VILLAGE/ TUBEWELL	PWB (Rs 000) TOTAL	NPWB (Rs 000)	BCR	RATIO NPWB : CAPITAL
CLUSTER 6																	
6	5	2	5a	5	2 199	123	1684	1807	185	3737	3921	0	5483	5483	1561	1 398	0 864
	8	1	5	8	2 199	123	600	723	185	1334	1519	0	1964	1964	445	1 293	0 616
	CLUSTER TOTAL				4 398	246	2284	2531	369	5071	5440	0	7447	7447	2007	1 369	0 793

CASE 2 ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES AND TUBEWELLS FOR DIFFERENT OPTIONS

22-Jun-88

Sr No	VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	FWB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPWB NPWB (Rs 000)	BCR	RATIO NPWB : CAPITAL
A VILLAGES																	
1	1	1	0	1	0.643	36	1142	1178	54	2521	2575	0	3691	3691	1116	1.433	0.947
2	2	1	0	2	2.521	141	1022	1163	212	2263	2475	0	3322	3322	847	1.342	0.728
		2	1	2	2.038	114	1022	1136	171	2263	2434	0	3322	3322	888	1.365	0.781
3	3	1	0	3	3.218	180	638	818	270	1412	1682	0	2078	2078	396	1.235	0.484
		2	2	3	1.877	105	638	743	158	1412	1570	0	2078	2078	508	1.324	0.684
		3	3a	3	2.521	141	638	779	212	1412	1624	0	2078	2078	454	1.280	0.583
4	4	1	0	4	4.022	225	973	1199	338	2158	2496	0	3171	3171	676	1.271	0.564
		2	3	4	1.073	60	973	1033	90	2158	2248	0	3171	3171	924	1.411	0.894
		3	4a	4	0.590	33	973	1006	50	2158	2207	0	3171	3171	964	1.437	0.958
5	5	1	0	5	3.486	195	1684	1879	293	3737	4029	0	5483	5483	1453	1.361	0.773
		2	5a	5	2.139	123	1684	1807	185	3737	3921	0	5483	5483	1561	1.398	0.864
6	6	1	0	6	2.843	159	1692	1852	239	3748	3987	0	5502	5502	1516	1.380	0.819
7	7	1	0	7	6.114	342	3058	3401	514	6774	7288	0	9943	9943	2656	1.364	0.781
		2	2a	7	4.773	267	3058	3326	401	6774	7175	0	9943	9943	2768	1.386	0.832
		3	4	7	4.237	237	3058	3296	356	6774	7130	0	9943	9943	2813	1.395	0.854
8	8	1	5	8	2.139	123	600	723	185	1334	1519	0	1564	1564	445	1.293	0.616
		2	8a	8	2.521	141	600	741	212	1334	1546	0	1564	1564	418	1.271	0.564
9	9	1	0	9	5.149	288	1208	1496	433	2669	3101	0	3899	3899	798	1.257	0.533
		2	5	9	3.003	168	1208	1376	252	2669	2921	0	3899	3899	978	1.335	0.711
10	10	1	0	10	4.881	273	741	1014	410	1641	2051	0	2401	2401	350	1.171	0.245
		2	6	10	2.950	165	741	906	248	1641	1889	0	2401	2401	513	1.271	0.566
11	11	1	0	11	3.486	195	1718	1913	293	3805	4098	0	5583	5583	1485	1.362	0.776
		2	1	11	3.003	168	1718	1886	252	3805	4058	0	5583	5583	1526	1.376	0.809
12	12	1	0	12	4.881	273	1108	1381	410	2452	2862	0	3590	3590	728	1.254	0.527
		2	1	12	4.237	237	1108	1345	356	2452	2808	0	3590	3590	782	1.278	0.581
		3	2	12	2.628	147	1108	1255	221	2452	2673	0	3590	3590	917	1.343	0.731
13	13	1	0	13	6.275	351	1270	1621	527	2817	3344	0	4143	4143	799	1.239	0.493
		2	2	13	3.552	216	1270	1486	324	2817	3141	0	4143	4143	1002	1.319	0.674
		3	12	13	1.443	81	1270	1351	122	2817	2938	0	4143	4143	1204	1.410	0.891
14	14	1	0	14	5.578	312	1396	1708	469	3093	3562	0	4535	4535	973	1.273	0.570
		2	1	14	4.881	273	1396	1669	410	3093	3503	0	4535	4535	1032	1.295	0.618
		3	12	14	1.609	90	1396	1486	135	3093	3228	0	4535	4535	1307	1.405	0.879

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CASE 2 : ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES AND TUBEWELLS FOR DIFFERENT OPTIONS

22-Jun-??

Sr No	VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE Km	CAPITAL COST (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PVB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPVB NPVB (Rs 000)	BCR	RATIO NPVB / CAPITAL
15	15	1	9	15	5 382	157	1210	1368	536	2674	3210	0	3907	3907	696	1 217	0 444
		2	2	15	3 808	213	1210	1424	320	2674	2994	0	3907	3907	913	1 305	0 641
		3	12	15	2 628	147	1210	1357	221	2674	2895	0	3907	3907	1012	1 349	0 745
		4	13	15	1 984	111	1210	1321	167	2674	2841	0	3907	3907	1066	1 373	0 807
16	16	1	3	16	1 555	87	1069	1156	131	2366	2496	0	3468	3468	972	1 389	0 841
8 TUBEWELLS																	
1	A1	1	0	A1	6 239	349	127	476	524	276	800	0	504	504	-296	0 631	-0 622
		2	A2	A1	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
2	A2	1	0	A2	5 149	288	127	415	433	276	709	0	504	504	-205	0 711	-0 493
		2	9	A2	0 644	36	127	163	54	276	330	0	504	504	174	1 525	1 067
3	A3	1	0	A3	4 193	234	127	361	351	276	628	0	504	504	-124	0 802	-0 342
		2	A3a	A3	0 268	15	127	142	23	276	299	0	504	504	205	1 687	1 443
4	A4	1	0	A4	4 193	234	127	361	351	276	628	0	504	504	-124	0 802	-0 342
		2	A4a	A4	0 805	45	127	172	68	276	344	0	504	504	160	1 466	0 932
5	A5	1	0	A5	4 344	243	127	370	365	276	641	0	504	504	-137	0 786	-0 370
		2	A5a	A5	0 054	3	127	130	5	276	281	0	504	504	223	1 795	1 729
6	A6	1	0	A6	5 310	297	127	424	446	276	722	0	504	504	-218	0 699	-0 514
		2	10	A6	1 297	72	127	199	108	276	384	0	504	504	120	1 312	0 602
7	A7	1	0	A7	6 651	372	127	499	559	276	835	0	504	504	-331	0 604	-0 663
		2	A6	A7	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
8	B1	1	0	B1	5 471	306	127	433	460	276	736	0	504	504	-232	0 685	-0 535
		2	B2	B1	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
9	B2	1	0	B2	3 969	222	127	349	333	276	610	0	504	504	-106	0 827	-0 302
		2	5	B2	1 394	78	127	205	117	276	393	0	504	504	111	1 282	0 541
10	B3	1	0	B3	2 682	150	127	277	225	276	501	0	504	504	3	[illegible]	[illegible]
		2	6	B3	1 448	81	127	208	122	276	398	0	504	504	106	1 297	[illegible]
11	B4	1	0	B4	2 145	120	127	247	180	276	456	0	504	504	48	[illegible]	[illegible]
		2	B4a	B4	0 268	15	127	142	23	276	299	0	504	504	205	[illegible]	[illegible]
12	B5	1	0	B5	2 843	159	127	286	239	276	515	0	504	504	-11	[illegible]	[illegible]
		2	C5	B5	1 663	93	127	220	140	276	416	0	504	504	88	1 212	[illegible]

CASE 2 ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES AND TUBEWELLS FOR DIFFERENT OPTIONS

22-Jun-88

Sr No	VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPWB NPWB (Rs 000)	BCR	RATIO NPWB CAPITAL
13	E6	1	0	E6	4 237	237	127	364	356	276	632	0	504	504	-128	0 797	-0 352
		2	11	E6	1 234	69	127	196	104	276	380	0	504	504	124	1 327	0 634
14	E7	1	0	E7	5 759	321	127	448	482	276	758	0	504	504	-254	0 665	-0 567
		2	E6	E7	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
15	C1	1	0	C1	5 091	285	127	412	428	276	704	0	504	504	-200	0 716	-0 485
		2	C1a	C1	0 268	15	127	142	23	276	299	0	504	504	205	1 587	1 443
16	C2	1	0	C2	3.379	189	127	316	284	276	560	0	504	504	-55	0 890	-0 177
		2	C2a	C2	0 107	6	127	133	9	276	285	0	504	504	219	1 767	1 643
17	C3	1	0	C3	1 603	90	127	217	135	276	411	0	504	504	93	1 225	0 427
		2	C3a	C3	1 073	60	127	187	90	276	366	0	504	504	138	1 376	0 737
18	C4	1	0	C4	0 429	24	127	151	36	276	312	0	504	504	192	1 614	1 272
		2	C4a	C4	0 107	6	127	133	9	276	285	0	504	504	219	1 767	1 643
19	C5	1	0	C5	1 877	105	127	232	158	276	434	0	504	504	70	1 162	0 303
		2	C5a	C5	0 134	8	127	134	11	276	287	0	504	504	217	1 753	1 613
20	C6	1	0	C6	3 647	204	127	331	306	276	583	0	504	504	-79	0 865	-0 237
		2	11	C6	0 536	30	127	157	45	276	321	0	504	504	183	1 569	1 166
21	C7	1	0	C7	5 363	300	127	427	450	276	727	0	504	504	-223	0 694	-0 521
		2	C6	C7	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
22	D1	1	0	D1	5 256	294	127	421	442	276	718	0	504	504	-214	0 702	-0 507
		2	D1a	D1	1 126	63	127	190	95	276	371	0	504	504	133	1 353	0 702
23	D2	1	0	D2	3 647	204	127	331	306	276	583	0	504	504	-79	0 865	-0 237
		2	D2a	D2	0 375	21	127	148	32	276	308	0	504	504	156	1 636	1 318
24	D3	1	0	D3	2 038	114	127	241	171	276	447	0	504	504	57	1 127	0 235
		2	D3a	D3	0 429	24	127	151	36	276	312	0	504	504	192	1 614	1 272
25	D4	1	0	D4	1 287	72	127	199	108	276	384	0	504	504	120	1 312	0 602
		2	D4a	D4	0 697	39	127	166	59	276	335	0	504	504	169	1 506	1 021
26	D5	1	0	D5	2 253	126	127	253	189	276	465	0	504	504	39	1 083	0 152
		2	D5a	D5	0 858	48	127	175	72	276	348	0	504	504	156	1 447	0 891
27	D6	1	0	D6	3 862	216	127	343	324	276	601	0	504	504	-97	0 839	-0 282
		2	E6	D6	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
28	D7	1	0	D7	5 524	309	127	436	464	276	740	0	504	504	-236	0 681	-0 542
		2	14	D7	1 341	75	127	202	113	276	389	0	504	504	115	1 296	0 571

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CASE 2 : ECONOMIC ANALYSIS OF ALL OPTIONS TO ELECTRIFY VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY VILLAGES AND TUBEWELLS FOR DIFFERENT OPTIONS

22-Jun-88

Sr No	VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE 1a	CAPITAL COST (RS 000) LINE	VILLAGE/ TUBEWELL	TOTAL	FWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	FWB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPWB NPWB (Rs 000)	BCR	RATIO NPWB / CAPITAL
29	E1	1 0	E1		5 953	333	127	460	500	276	776	0	504	504	-272	0 649	-0 592
		2 E1a	E1		0 375	21	127	148	32	276	308	0	504	504	196	1 638	1 328
30	E2	1 0	E2		4 559	255	127	382	383	276	659	0	504	504	-155	0 765	-0 406
		2 E2a	E2		1 126	63	127	190	95	276	371	0	504	504	133	1 353	0 702
31	E3	1 0	E3		3 486	195	127	322	293	276	569	0	504	504	-65	0 866	-0 202
		2 4	E3		0 637	39	127	166	59	276	335	0	504	504	163	1 506	1 021
32	E4	1 0	E4		3 111	174	127	301	261	276	538	0	504	504	-34	0 938	-0 111
		2 E4a	E4		0 268	15	127	142	23	276	299	0	504	504	205	1 687	1 443
33	E5	1 0	E5		2 574	144	127	271	216	276	492	0	504	504	12	1 024	0 043
		2 E5a	E5		0 483	27	127	154	41	276	317	0	504	504	167	1 531	1 217
34	E6	1 0	E6		4 827	270	127	397	405	276	682	0	504	504	-178	0 739	-0 447
		2 12	E6		0 215	12	127	139	18	276	294	0	504	504	210	1 713	1 511
35	E7	1 0	E7		6 618	371	127	497	556	276	832	0	504	504	-328	0 606	-0 660
		2 14	E7		0.644	36	127	163	54	276	330	0	504	504	174	1 526	1 067
36	F1	1 0	F1		7 026	393	127	520	590	276	866	0	504	504	-362	0 582	-0 637
		2 E1	F1		1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
37	F2	1 0	F2		5 953	333	127	460	500	276	776	0	504	504	-272	0 649	-0 592
		2 E2	F2		1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
38	F3	1 0	F3		5 095	285	127	412	428	276	704	0	504	504	-200	0 716	-0 486
		2 16	F3		0 429	24	127	151	36	276	312	0	504	504	192	1 614	1 272
39	F4	1 0	F4		4 827	270	127	397	405	276	682	0	504	504	-178	0 739	-0 447
		2 16	F4		1 073	60	127	187	90	276	366	0	504	504	138	1 376	0 737
40	F5	1 0	F5		5 149	288	127	415	433	276	709	0	504	504	-205	0 711	-0 493
		2 15	F5		1 555	87	127	214	131	276	407	0	504	504	97	1 239	0 455
41	F6	1 0	F6		6 007	336	127	463	505	276	781	0	504	504	-277	0 646	-0 598
		2 F6a	F6		0 215	12	127	139	18	276	294	0	504	504	210	1 713	1 511
42	F7*	1 0	F7		7 189	403	127	529	604	276	880	0	504	504	-376	0 573	-0 710
		2 13	F7		1 126	63	127	190	95	276	371	0	504	504	133	1 353	0 702

CASE 2a ECONOMIC ANALYSIS TO ELECTRIFY CLUSTERS OF VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES AND TUBEWELLS

22-Jun-88

Sr No	CLUSTER No / OPTION VILLAGE No / TUBEWELL LOAD CENTER	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PVC (Rs. 000) LINE	VILLAGE/ TUBEWELL	TOTAL	FVB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NFVB (Rs 000)	BCR	RATIO NFVB : CAPITAL
CLUSTER 1																
1	1	1	0	1	0.643	36	1142	1178	54	2521	2575	0	3691	3691	1116	1.435	0.947
	11	2	1	11	3.003	168	1718	1886	252	3805	4058	0	5553	5553	1526	1.376	0.809
	B5	2	C5	B5	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	B6	2	11	B6	1.234	69	127	196	104	276	280	0	504	504	124	1.[illegible]	0.624
	B7	2	B6	B7	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	C5	2	C5a	C5	0.134	8	127	134	11	276	287	0	504	504	217	1.753	1.613
	C6	2	11	C6	0.536	30	127	157	45	276	321	0	504	504	183	1.569	1.166
	C7	2	C6	C7	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	CLUSTER TOTAL				10.539	601	4221	8431	9316	17300	26163	26163	32446	6274	1.[illegible]	1.240	2.317
CLUSTER 2																
2	12	3	2	12	2.628	147	1108	1255	221	2452	2673	0	3590	3590	917	1.343	0.731
	13	3	12	13	1.448	81	1270	1351	122	2817	2938	0	4143	4143	1204	1.410	0.891
	14	3	12	14	1.609	90	1396	1486	135	3093	3228	0	4535	4535	1307	1.405	0.879
	15	4	13	15	1.984	111	1210	1321	167	2674	2841	0	3907	3907	1066	1.375	0.807
	D6	2	E6	D6	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	D7	2	14	D7	1.341	75	127	202	113	276	389	0	504	504	115	1.296	0.571
	E5	2	E5a	E5	0.483	27	127	154	41	276	317	0	504	504	187	1.591	1.217
	E6	2	12	E6	0.215	12	127	139	18	276	294	0	504	504	210	1.713	1.511
	E7	2	14	E7	0.644	36	127	163	54	276	330	0	504	504	174	1.528	1.067
	F5	2	15	F5	1.555	87	127	214	131	276	407	0	504	504	97	1.[illegible]	0.455
	F6	2	F6a	F6	0.215	12	127	139	18	276	294	0	504	504	210	1.713	1.511
	F7	2	13	F7	1.126	63	127	190	95	276	371	0	504	504	133	1.359	0.702
	CLUSTER TOTAL				14.911	835	5998	6833	1253	13246	14499	0	20207	20207	5708	1.394	0.835
CLUSTER 3																
3	6	1	0	6	2.843	159	1692	1852	239	3748	3987	0	5502	5502	1516	1.[illegible]	0.819
	9	2	6	9	3.003	168	1208	1376	252	2669	2921	0	3899	3899	978	1.[illegible]	0.711
	10	2	6	10	2.950	165	741	906	248	1641	1889	0	2401	2401	513	1.271	0.566
	A1	2	A2	A1	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	A2	2	9	A2	0.644	36	127	163	54	276	330	0	504	504	174	1.528	1.067
	A3	2	A3a	A3	0.269	15	127	142	23	276	299	0	504	504	205	1.[illegible]	1.443
	A4	2	A4a	A4	0.805	45	127	172	68	276	344	0	504	504	[illegible]	1.466	0.[illegible]

CASE 2a : ECONOMIC ANALYSIS TO ELECTRIFY CLUSTERS OF VILLAGES AND TUBEWELLS
DISTRICT GHAZIABAD, TEHSIL GHAZIABAD (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES AND TUBEWELLS

22-Jun-88

Sr No.	CLUSTER No / VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE Km	CAPITAL COST (RS 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWC (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	PWB (Rs 000) LINE	VILLAGE/ TUBEWELL	TOTAL	NPWB (Rs 000)	BCR	RATIO NPWB/ CAPITAL
	A5	2	A5a	A5	0 054	3	127	130	5	276	281	0	504	504	223	1 795	1 720
	A6	2	10	A6	1 287	72	127	199	103	276	364	0	504	504	120	1 312	0 602
	A7	2	A6	A7	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
	B3	2	6	B3	1 448	81	127	208	122	276	398	0	504	504	106	1 267	0 511
	B4	2	B4a	B4	0 268	15	127	142	23	276	299	0	504	504	205	1 687	1 448
	C4	2	C4a	C4	0 107	6	127	133	9	276	285	0	504	504	219	1 767	1 648
	CLUSTER TOTAL				17 003	952	4909	5861	1428	10819	12247	0	16843	16843	4535	1 375	0 734
CLUSTER 4																	
	7	1	0	7	6 114	342	3059	3401	514	6774	7288	0	9943	9943	2656	1 364	0 781
	C3	2	C3a	C3	1 073	60	127	187	90	276	366	0	504	504	138	1 376	0 737
	D1	2	D1a	D1	1 126	63	127	190	95	276	371	0	504	504	133	1 359	0 702
	D2	2	D2a	D2	0 375	21	127	148	32	276	308	0	504	504	196	1 638	1 328
	D3	2	D3a	D3	0 429	24	127	151	36	276	312	0	504	504	192	1 614	1 272
	E1	2	E1a	E1	0 375	21	127	148	32	276	308	0	504	504	196	1 638	1 328
	E2	2	E2a	E2	1 126	63	127	190	95	276	371	0	504	504	133	1 359	0 702
	F1	2	E1	F1	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
	F2	2	E2	F2	1 663	93	127	220	140	276	416	0	504	504	88	1 212	0 401
	CLUSTER TOTAL				13 944	781	4073	4853	1171	8984	10155	0	13975	13975	3820	1 376	0 787
CLUSTER 5																	
	2	2	1	2	2 038	114	1022	1136	171	2263	2434	0	2922	2922	488	1 285	0 431
	3	2	2	3	1 877	105	638	743	158	1412	1570	0	2073	2073	503	1 324	0 684
	4	3	4a	4	0 590	33	973	1006	50	2158	2207	0	3171	3171	964	1 437	0 958
	16	1	3	16	1 555	87	1069	1156	131	2366	2496	0	3468	3468	972	1 389	0 841
	D4	2	D4a	D4	0 697	39	127	166	59	276	335	0	504	504	169	1 506	1 021
	D5	2	D5a	D5	0 858	48	127	175	72	276	348	0	504	504	156	1 447	0 891
	E3	2	4	E3	0 697	39	127	166	59	276	335	0	504	504	169	1 506	1 021
	E4	2	E4a	E4	0 268	15	127	142	23	276	299	0	504	504	205	1 687	1 448
	F3	2	16	F3	0 429	24	127	151	36	276	312	0	504	504	192	1 614	1 272
	F4	2	16	F4	1 073	60	127	187	90	276	366	0	504	504	138	1 376	0 737
	CLUSTER TOTAL				10 082	565	4463	5028	847	9856	10703	0	15064	15064	4361	1 4[illegible]	0 867

CASE 2a : ECONOMIC ANALYSIS TO ELECTRIFY CLUSTERS OF VILLAGES AND TUBEWELLS
DISTRICT OKARA, TEHSIL OKARA (16 SAMPLE VILLAGES)

ECONOMIC BENEFIT-COST RATIO BY CLUSTER OF VILLAGES AND TUBEWELLS

22-Jun-88

Sr No	CLUSTER No / VILLAGE No / TUBEWELL LOAD CENTER	OPTION	FROM	TO	HT LINE km	CAPITAL COST (RS. 000) LINE	CAPITAL COST (RS. 000) VILLAGE/ TUBEWELL	CAPITAL COST (RS. 000) TOTAL	PWC (Rs. 000) LINE	PWC (Rs. 000) VILLAGE/ TUBEWELL	PWC (Rs. 000) TOTAL	PWB (Rs 000) LINE	PWB (Rs 000) VILLAGE/ TUBEWELL	PWB (Rs 000) TOTAL	NPWB (Rs.000)	BCR	RATIO NPWB : CAPITAL
CLUSTER 6																	
6	5	2	5a	5	2.199	123	1684	1807	185	3737	3921	0	5483	5483	1561	1.398	0.864
	6	1	5	8	2.199	123	600	723	185	1334	1519	0	1964	1964	445	1.293	0.616
	B1	2	B2	B1	1.663	93	127	220	140	276	416	0	504	504	88	1.212	0.401
	B2	2	5	B2	1.384	78	127	205	117	276	393	0	504	504	111	1.282	0.541
	C1	2	C1a	C1	0.268	15	127	142	23	276	299	0	504	504	205	1.687	1.448
	C2	2	C2a	C2	0.107	6	127	133	9	276	285	0	504	504	219	1.767	1.648
	CLUSTER TOTAL				7.830	438	2791	3230	658	6176	6833	0	9463	9463	2630	1.385	0.814

NWFP
District Bannu, Tehsil Lakki Marwat

CUMULATIVE METHOD

Feeder A	NPV Benefits	NPV Village Costs	NPV Line Costs	Cumulative Benefits	Cumulative Costs	B/C Ratio	RANK Initial	RANK Adjusted
Branch A1								
2a	0	0	185	0	185	0.00		
2	1776	556	5	1776	746	2.38	7	10
9	8621	3246	554	10397	4546	2.29	10	12
Branch A2								
2a	0	0	185	0	185	0.00		
3	14321	4465	281	14321	4931	2.89	1	1
Feeder B								
Branch B1								
4a	0	0	550	0	550	0.00		
4	4982	1552	290	4982	2392	2.08	17	19
Branch B2								
4a	0	0	550	0	550	0.00		
5	1916	603	294	1916	1147	1.32	21	
10a	0	0	296	1916	1743	1.10		
10	4982	1552	68	6898	3383	2.04	19	20
Branch B3								
4a	0	0	550	0	550	0.00		
5	1916	603	294	1916	1447	1.32	20	16
10a	0	0	296	1916	1743	1.10		
11	7915	2475	384	9831	4602	2.14	15	17
12	2567	801	403	12398	5806	2.14	16	18
Feeder C								
Branch C1								
6a	0	0	600	0	600	0.00		
6	1605	498	227	1605	1325	1.21	22	21
Branch C2								
6a	0	0	600	0	600	0.00		
15a	0	0	598	0	1198	0.00		
16	11358	3550	138	11358	4886	2.32	8	11
Branch C3								
6a	0	0	600	0	600	0.00		
15a	0	0	598	0	1198	0.00		
15	8851	2769	101	8851	4068	2.18	14	7
14	4542	1424	315	13393	5807	2.31	9	8
13	7967	2493	239	21360	8539	2.50	6	9
Feeder D								
Branch D1								
1a	0	0	180	0	180	0.00		
1	6821	2129	68	6821	2397	2.85	2	2
8	3485	1069	441	10306	3927	2.62	3	3
Branch D2								
1a	0	0	180	0	180	0.00		
7a	0	0	339	0	519	0.00		
7	6840	2134	428	6840	3081	2.22	12	15
Branch D3								
1a	0	0	180	0	180	0.00		
7a	0	0	339	0	519	0.00		
17a	0	0	339	0	858	0.00		
17	7251	2274	403	7251	3535	2.05	18	13
21	5019	1564	315	12270	5414	2.27	11	14
Branch D4								
1a	0	0	180	0	180	0.00		
7a	0	0	339	0	519	0.00		
17a	0	0	339	0	858	0.00		
18	6751	2130	110	6751	3098	2.18	13	4
19	7738	2417	128	14489	5643	2.57	5	5
20	4584	1437	340	19073	7420	2.57	4	6

District Bannu, Tensil Lakki Marwat

MARGINAL INCREMENTAL METHOD

To Point:	From Point:	NPV Benefits	NPV Village Costs	NPV Line Costs	Benefit/ Cost Ratio	From Point:	Benefit/ Cost Ratio	Rank
Feeder A								
2a	0	0	0	165	0.00			
2	2a	1776	556	5	3.17	0	2.38	2
9	2	8621	3246	554	2.27			15
3	2a	14321	4465	281	3.00	0	2.69	1
								(#1)
Feeder B								
4a	0	0	0	550	0.00			
4	4a	4982	1552	290	2.70	0	2.08	17
5	4a	1916	603	294	2.14			18
10a	5	0	0	296	0.00			
10	10a	4982	1552	88	3.04	5	2.57	19
11	10a	7915	2475	384	2.77	5	2.51	20
12	11	2567	801	403	2.13			21
								#4
Feeder C								
6a	0	0	0	600	0.00			
6	6a	1605	498	227	2.21	0	1.21	16
15a	6a	0	0	598	0.00			
16	15a	11358	3550	138	3.08	0	2.32	10
15	15a	8851	2769	101	3.08	0	2.18	11
14	15	4542	1424	315	2.61			12
13	14	7967	2493	239	2.92			13
								#3
Feeder D								
1a	0	0	0	180	0.00			
1	1a	6821	2129	68	3.08	0	2.85	3
8	1	3485	1069	441	2.28			14
7a	1a	0	0	339	0.00			
7	7a	6840	2134	428	2.67	1a	2.36	4
17a	7a	0	0	339	0.00			
17	17a	7251	2274	403	2.71			7
21	17	5019	1564	315	2.67			8
18	17a	6751	2130	110	3.01	7a	2.62	
18						1a	2.31	5
19	18	7738	2417	126	3.04			6
20	19	4584	1437	340	2.58			9
								#2

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TOTAL INCREMENTAL METHOD

Village Number	NPV Benefits	NPV Vill Costs	NPV Line Cost	Cumulative Benefits	Cumulative Costs	B/C Ratio	Rank
Feeder A							
9	8621	3246	554	8621	3800	2.27	19
2	1776	336	5	10397	4361	2.38	17
2	14321	4485	281	14321	4766	3.00	1
2a	0	0	185	24718	9312	2.65	
						#1	
Feeder B							
12	2567	801	403	2567	1204	2.13	21
11	7915	2475	384	10482	4063	2.58	16
10	4962	1552	88	4962	1640	3.04	15
10a	0	0	296	15464	5999	2.58	
5	1916	603	294	17380	6896	2.52	14
4	4982	1552	290	4982	1842	2.70	13
4a	0	0	550	22362	9288	2.41	
						#4	
Feeder C							
13	7967	2493	239	7967	2732	2.92	11
14	4542	1424	315	12509	4471	2.80	10
15	8851	2769	101	21360	7341	2.91	9
16	11358	3550	138	11358	3688	3.08	8
15a	0	0	598	32718	11627	2.81	
6	1605	498	227	1605	725	2.21	20
6a	0	0	600	34323	12952	2.65	
						#3	
Feeder D							
20	4584	1437	340	4584	1777	2.58	12
19	7738	2417	128	12322	4322	2.85	4
18	6751	2130	110	19073	6562	2.91	3
21	5019	1564	315	5019	1879	2.67	6
17	7251	2274	403	12270	4556	2.69	5
17a	0	0	339	31343	11457	2.74	
7	6840	2134	428	6840	2562	2.67	7
7a	0	0	339	38183	14358	2.66	
8	3465	1089	441	3465	1530	2.28	18
1	6821	2129	68	10306	3747	2.75	2
1a	0	0	180	48489	18285	2.65	
						#2	

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NWFP
District Bannu, Tehsil Lakki Marwat

CLUSTER METHOD

Feeder A	NPV Benefits	NPV Village Costs	NPV Line Costs	Cumulative Benefits	Cumulative Costs	Benefit/ Cost Ratio	Rank
2a	0	0	185	0	185	0.00	
2	1776	556	5	1776	746	2.38	
3	8621	3246	554	10397	4546	2.29	
1	14321	4465	281	24718	9312	2.65	1
Feeder B							
4a	0	0	550	0	550	0.00	
4	4982	1552	290	4982	2392	2.08	
5	1916	603	294	6898	3289	2.10	
10a	0	0	296	6898	3585	1.92	
10	4982	1552	88	11880	5225	2.27	
11	7915	2475	384	19795	8064	2.45	
12	2567	801	403	22362	9288	2.41	4
Feeder C							
6a	0	0	600	0	600	0.00	
6	1605	498	227	1605	1325	1.21	
15a	0	0	598	1605	1923	0.83	
16	11358	3550	138	12963	5611	2.31	
15	8851	2769	101	21814	8481	2.57	
14	4542	1424	315	26356	10220	2.58	
13	7967	2493	239	34323	12952	2.65	3
Feeder D							
1a	0	0	180	0	180	0.00	
1	6821	2129	88	6821	2397	2.85	
8	3485	1089	441	10306	3927	2.62	
7a	0	0	339	10306	4266	2.42	
7	6840	2134	426	17146	6628	2.51	
17a	0	0	339	17146	7167	2.39	
17	7251	2274	403	24397	9844	2.48	
21	5019	1564	315	29416	11723	2.51	
18	6751	2130	110	36167	13963	2.59	
19	7738	2417	128	43905	16508	2.66	
20	4564	1437	340	48469	18265	2.65	2

Supporting Data and Analysis for Baluchistan Case Study: District Kalat (Decentralized Generation Costs Using Diesel Fuel)

Diesel Plant Capital Costs

These capital costs were based on the Energy Wing study of decentralized generation (Ref 32). The graph illustrating unit capital costs (Rs/kW) as a function of kW size was simplified into a linear function for a range of about 10 to 60 kW based on two points: 14,000 Rs/kW at 20 kW and 6,000 Rs/kW at 5o kW. The simplified formula is

Unit Capital Costs in Rs/kW for size "X" =

(14,000 - (270 * (X - 20)))

In the future, a more precise formula which covers a broader range of sizes should be developed. The size of the diesel plant was equal to the peak demand increased by 20 percent as a reserve margin. This same reserve margin was used for the central grid. The capital cost for generation and transmission for the central grid is only based on 65 percent of the peak demand due to the peak coincidence or diversity factor at the point of generation; this peak demand at generation was increased by the 20 percent reserve margin.

Diesel Recurrent Costs

These costs are for diesel duel, lubricating oil, and other operating and maintenance costs. The other maintenance and operating costs are fixed and were estimated to be 20 percent of the capital cost annually. The fuel costs were based on about 20 percent generation efficiency or 0.50 liters HSD per kWh at a cost of 4 Rs/liter. The lubricating oil cost is based on 8 Rs/liter and a consumption rate of one liter per 12 liters of HSD.

Since the BCR's are calculated using the present value of benefits and costs, the recurrent costs were assumed constant for the assumed life of the diesel plant of seven years. The present value was based on seven years and a 10 percent discount rate.

Other Costs

The HT line costs connecting villages using the diesel generation are assumed to be 56,000 Rs/km with 5 percent operating and maintenance costs annually. In present value terms, the total cost of the line is about 84,000 Rs/km assuming a 30 year life and a 10 percent discount rate. This figure is the same as that used for area distribution from the central grid, and it should be refined to reflect the differences between these two application. Line losses are not included.

Village distribution costs (LT lines and distribution transformers) are taken to be 1750 Rs/kW demanded. This cost is assumed to be the same cost as used under central grid electrification. This figure should also be refined.

APPENDIX I
DEVELOPMENT POTENTIAL INDICIES

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DEVELOPMENT RANKING OF DISTRICTS OF PAKISTAN

Hafiz A. PASHA and Tariq HASAN*

This paper employs two different techniques – the ZSUM and Weighted Factor Score – and twenty-seven indicators to quantify the levels of development in the districts of Pakistan in the 1970s. The magnitude of development indicators in relatively underdeveloped districts are analyzed to construct a profile of backwardness. Also, our rankings are compared with those obtained by Helbock and Naqavi (1976) for Pakistan in the 1960s.

I. Introduction

The existence of significant regional variation in level of development in Pakistan is a widely recognized fact. The two provinces of Baluchistan and the North West Frontier Province (NWFP) are generally seen as relatively backward while the two other provinces, Sind and Punjab, are considered as relatively developed. This is reflected in the nature of federal subventions and grants-in-aid. However, this level of regional generalization masks large intra-provincial disparities at the district or at the tehsil/taluka level. It is necessary, therefore, to have knowledge of the variation in the level of development at a more regionally disaggregated level so as to be able to identify more precisely the location of the poorer segments of the national population from the viewpoint of provision of basic infrastructure and services.

However, research on regional levels of development in Pakistan has been severely constrained by the lack of data at the district level. The objective of this study, therefore, is to make a first attempt at the quantification of the level of development attained by each district of Pakistan. It needs to be emphasized at this stage that development has not been seen simply in terms of the level of per capita income for a number of reasons. Firstly, in an economy like that of Pakistan where almost 75 percent of the population is rural and agriculture is characterized primarily by traditional,

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subsistence farming, per capita income is likely to be a distorted measure of welfare because of changes in the quality of goods, access to services, in the extent of leisure and decline over time in the share of non-marketed products. Secondly, if development is viewed as a multidimensional and not a purely economic phenomenon, then the use of per capita income as the sole indicator of development is open to criticism. Therefore, a number of development indicators have been defined, including per capita income, in this study to measure the level of development of individual districts.

The paper is organized as follows: Section II gives a description of the development indicators included. Summary statistics of the distribution of indicators at the district level are presented in section III. The techniques used for deriving a composite indicator of the level of development from the individual indicators are described in section IV.[1] Section V presents the results of the application of these techniques in terms of their implications about the interaction of different factors during the process of development. Section VI identifies the relatively developed and underdeveloped districts of Pakistan. In this section an attempt is also made to see if the development ranking of districts is sensitive to the choice of technique for measuring level of development. Section VII identifies the lagging sectors in the relatively underdeveloped districts thereby indicating the nature of backwardness in Pakistan. Section VIII attempts to determine the trend over time in regional disparities and provides a preliminary answer to the question as to whether such disparities have tended to narrow or widen. Finally, section IX contains a summary of the principal findings and conclusions.

II. Choice of Development Indicators

As mentioned above, the traditional approach of using per capita income as the sole indicator of development has been largely discarded. It is now recognized that development is a complex process which involves basic social and political changes in a society as well as growth in per capita income. Furthermore, at different levels of development the relationship between social, political and economic variables is likely to be different, as highlighted by Adelman and Morris (1967). Therefore, a multidimensional approach to the measurement of development must emphasize both changes in the capacity to attain development objectives as well as the actual attainment of these objectives. This means that development indicators could acquire an operational significance for planning purposes.

The choice of development indicators at the district level in this study

[1] Readers who are primarily interested in the results of the study and not in the methodology may skip section IV.

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has been governed by a number of considerations. Firstly, an attempt has been made to achieve as wide a sectoral coverage as possible through the indicators. As such, indicators have been selected to highlight the development of sectors like agriculture, industry, education, health, housing, transport and telecommunications. Secondly, two alternatives were available regarding the choice of indicators: we could concentrate on measuring the consequences of development or the level of development inputs. Reliance has been placed on the latter approach primarily because of the relative absence of data on the former. For example, if the output approach had been adopted to measure the development of the health sector, the indicators used would have been life expectancy, infant mortality, etc. But since data was not available on these magnitudes at the district level, the alternative chosen was to quantify the level of inputs in the form of doctors, hospital beds, etc. Therefore, while there may have been some loss of precision in quantification of the level of development, the results are perhaps more operational in character from the planning viewpoint as the focus is more on development inputs.

The lack of data has not only constrained the approach to the construction of development indicators, but it has limited the number of development indicators and in some cases led to the choice of relatively crude proxies. Nevertheless, it has been possible to identify 27 indicators relating to different sectors.

Diverse sources of data have been used for quantifying the indicators. Firstly, reliance has been placed on the various censuses of population, manufacturing, housing, agriculture and livestock that have been carried out in Pakistan during the '70s. Secondly, relevant data has been collected from the published documents of the various ministries and departments of the Federal and Provincial governments. Thirdly, some primary data collection has been resorted to by establishing contacts with line departments like the Highways Department, Railway, etc. Finally, in some cases, unconventional sources of data have been tapped. For example, no published data was available on the total number of doctors, private and government, in each district. The approach adopted, therefore, was to contact the large pharmaceutical companies in the country who maintain an up-to-date list of doctor's addresses for purposes of sales promotion through their medical representatives. In this way, it was possible to derive the regional distribution of doctors.

Described below are the development indicators chosen in each sector along with their possible defects. A detailed description of the methodology of construction of the different indicators is given in the Statistical Appendix with a listing of the sources of data.

INCOME AND WEALTH

CROP CASH VALUE PER CAPITA (CASHV)

This is the basic indicator of the income level in the rural area of a district. The crop cash value (price multiplied by output) has been estimated for each crop, major and minor, and the individual crop cash values aggregated to arrive at the overall crop cash value. Thirty three crops were included in this exercise, which is described in detail in the Statistical Appendix. The aggregate crop cash value was then divided by the projected rural population to give the per capita cash value. This indicator has been constructed for the year 1975-76.

There are a number of problems with this indicator. Firstly, it is not comprehensive enough in coverage. It relates only to the value generated in the crop sector of the rural economy and misses out the income derived not only from other forms of agricultural activity like livestock, forestry and fishing, but also from non-agricultural occupations like small scale industry, trading, etc. The former gap has been covered partially by incorporating the value added in the fisheries sector into the cash value. This has raised the cash value of agricultural output primarily of the coastal districts like Lasbela and Mekran in Baluchistan province. Also, a separate indicator has been constructed for the livestock sector which is described below. It has not been possible, however, to adjust for the undercoverage of non-agricultrual activities in the rural sector due to the absence of data.

The second problem with the crop cash value per capita indicator is that it is sensitive to the random elements which characterize agriculture. For example, weather variations, pest attacks and floods could affect different districts to a varying extent. As such, it is necessary to take a year which is the more representative of the normal districtwise variations in cropping patterns and yield. The year, 1975-76, in fact, witnessed a major decline in cotton output due to floods and pest attack. Therefore, if total reliance was placed only on this year for estimating the crop cash value, it would tend to give a downward bias to the cash value of the major cotton-growing districts in the country. The adjustment procedure followed, therefore, is to replace the cotton output figures for the year 1975-76 by those of the last normal year which in this case was 1973-74.

Industrial Value Added Per Capita (INDVAD)

Data for the value added in the large-scale industrial sector was obtained from the latest census of manufacturing. This was divided by the projected

urban population for the year to arrive at the per capita industrial value added.

One of the basic problems with this indicator is that it excludes the value added in the small-scale industrial sector due to the lack of data. This is a significant exclusion as at the national level almost 30% of the total value added in manufacturing is estimated to originate from small-scale operations. It affects, in particular, some districts of Punjab like Sialkot, Sheikhupura, etc., where small-scale industry is concentrated and probably accounts for the major portion of the industrial value added.

Number of Commercial Bank Branches Per 100,000 Population (BANKS)

This is both an income and wealth indicator. The number of commercial bank branches in 1975-76 in each district has been divided by the projected total population of the district. It is clear that the number of commercial bank branches in a district is a relatively crude indicator of the income or wealth position of a district. A better indicator would have been the total volume of commercial bank deposits by type generated from the district. However, such information is not published either by the commercial banks or the central bank.

Number of Livestock Units Per Capita (LIVSTK)

Data is available currently on the number of livestock by type in each district, but no information is available on livestock output by type at the district level. Therefore, it is not possible to construct an income measure for the livestock sector. Instead, an indicator relating to wealth in the form of livestock has been defined. Different animals have been converted into equivalent units by assigning weights which are described in detail in the Statistical Appendix.

AGRICULTURE

The basic indicator of development of this sector is *crop cash value per capita* which has already been defined as an income indicator. A number of other indicators have been defined to capture the level of development of the agricultural sector. As mentioned earlier, the approach has been to quantify the inputs to development. In the context of agriculture, this has meant determination of the level of use of inputs like irrigation water, fertilizer, and tractors in each district. The indicators defined are *percentage of cultivated area irrigated (IRRIGATE)*, *percentage of cropped area fertilized (FERTILIZ)*, and *percentage of farmers using tractors (TRACTOR)*. The latest available data is for 1972.

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The problem with these three indicators is that while they probably adequately reflect the spread of technology, they do not capture inter-district variations in the intensity of use of irrigation water, fertilizer and tractors. In addition, if data had been available, an attempt would also have been made to quantify the use of other inputs like improved seeds, pesticides, etc.

Another indicator which has been defined to measure agricultural development is the *extent of commercialization of agriculture (COMMAG)*. It is argued that as development proceeds, subsistence farming is replaced by commercialized farming and the share of output marketed increases. Marketing, in this context, is defined not only as the net surplus marketed by the rural sector to urban areas, but also intra-rural marketing. It is essentially a measure of marketing at the individual farm and not at the sectoral level.

It has been assumed that bulk of the output of cash crops like cotton, sugarcane, rice, tobacco, fruits and vegetables, etc., is marketed. The major difficulty is in estimating the component of wheat output that is marketed. For this purpose, a special methodology has been developed which is described in the Statistical Appendix. Essentially, it consists of determining the net surplus-deficit by farm size category given estimates of production, home consumption and seed requirement of wheat.

The magnitude of this indicator has been derived for 1975-76 from the crop cash values estimated in the first indicator.

INDUSTRY

The basic indicator of industrial development is *industrial value added per capita* which has already been defined as an income indicator. Two other indicators have been defined. The first measures the *percentage of the urban labour force in industry (INDEMP)* and the second relates to the *percentage of industrial employment in intermediate and capital goods industries (CAPEMP)*. The defect with the former indicator is that it does not include employment in the small-scale industrial sector. The logic behind the inclusion of the latter indicator is that as industrialization proceeds, a greater share of industrial employment tends to get concentrated in relatively sophisticated industries manufacturing intermediate and capital goods, whereas in the initial stages of import substitution bulk of the employment is in consumer goods, particularly those based on processing of agricultural output. Such a pattern is also observed in international cross-country data on industry as demonstrated by Kuznets (1971).

HOUSING

Four indicators have been defined to measure the quality of housing stock in a district and access to basic services like water, electricity and gas. The indicators are *percentage of dwelling units which are pucca (PUCCA), with inside water connections (WATHSE), with electricity (ELECHSE) and with gas connections (GASHSE)*. Latest data on these four indicators was obtained for 1973.

The basic problem with the above indicators is that while they are able, more or less, to catch the access to basic services, they do not reflect variations in the level of per capita consumption of water, electricity and gas.

EDUCATION

Both stock and flow measures have been defined for the education sector. The stock measure is the *literacy rate (LITRATE)*, which indicates the level of literacy among the population aged ten years and above in a district.

Measures of flow of output from the education sector relate to *enrollment rates at the primary (PRIMARY), secondary (SECONDARY)*, and *college level (COLLEGE)*. The relevant school and college-age going populations in each district have been projected on the basis of intercensal growth rates for purposes of deriving the enrollment rates.

HEALTH

Two indicators of inputs into the health sector have been defined. The first relates to *doctors per 10,000 population (DOCTOR)* and the other to *hospital beds per 10,000 population (HOSPBED)*.

TRANSPORT AND COMMUNICATIONS

The development of the road transport sector is measured in terms of *metalled road mileage per 100 sq. miles of geographical area (METROAD)*, and *unmetalled road mileage per 100 sq. miles of geographical area (UNMTROAD)* for the year 1972. The latter relates to inter-district and inter-provincial highways while the former essentially catches the presence of farm-to-market roads.

Railway mileage per 100 sq. miles of geographical area (RAILWAY) enables the determination of the extent of railway network passing through a district. Weighting factors were used to allow for different types of gauge

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(broad gauge) and for single and double track, as described in the Statistical Appendix.

In the case of both the above indicators, preference was given to measuring the presence of transport network, in terms of mileage, in relation to geographical area over either population or cultivated area. Mileage in relation to population does not necessarily give a correct measure of access to transport because the network may pass only through the large urban concentrations and leave bulk of the rural areas largely inaccessible. Coverage with respect to cultivated area gives a somewhat better indication of access. However, it assumes, firstly, that bulk of the transport demand is essentially from the agricultural sector and, secondly, that the rural population is not widely dispersed. It is clear, for example, that if road or railway mileage is seen with respect to population and cultivated area and not in relation to geographical area, then the province of Baluchistan, the largest province of Pakistan in terms of geographical area, would appear to be relatively well endowed with transport infrastructure whereas, in fact, it is generally recognized that the transport sector is least developed in this province.

Given the road mileage, it is also important to determine the stock of vehicles in a district which influences the capacity of road transport. As such, another indicator has been defined, *passenger load carrying capacity per capita (PASLOAD)*, and different types of vehicles, viz, buses, cars, motorcycles, etc., have been aggregated by using weights equal to the passenger carrying capacity of each type of vehicle. These weights are given in the Statistical Appendix.

Development of telecommunications in a district has been quantified with the help of the indicator, *telephones per 1,000 population (TELPHON)*. Industrial, commercial and government connections have been excluded as they tend to overstate the magnitude of this development indicator in the case of districts that are playing an important administrative or commercial role, which is captured by other indicators.

SEXUAL EQUALITY

As development proceeds, it has been observed that one of the major social changes that occurs is the transformation in the role of women. Female literacy, school and college enrollment and labour force participation rates tend to rise. As such, indicators have been chosen to quantify the extent of sexual equality in the district. These are *female to male literacy rate (SEXLIT)* and *female to male primary and secondary enrollment rate (SEXENRL)*.

III. Summary Measures of Development Indicators

Magnitude of the development indicator for each district is given in Table S.1 in the Statistical Appendix. The district boundaries correspond to those that were prevailing at the time the population census of 1972 was carried out. Fortysix districts have been included in the analysis. Districts of the Malakand Division in the NWFP and the Centrally Administered Areas have not been included due to the almost complete paucity of data on these areas. About 93 percent of the national population is estimated to have been residing in the districts included in the study in 1972.

Three summary measures have been calculated to describe and compare the distributions of the indicators. These are respectively the first, second and third moments referred to as the mean, variance and skewness. In addition, the coefficient of variation has also been computed. The last two measures are perhaps the basic indicators of the extent of regional inequality. These measures are presented in Table 1. It needs to be pointed out that the means of the various indicators do not correspond to the national values of these indicators. This is because they are simple averages and not averages weighted by the population or area of the disctiets depending upon the indicator.

Highest dispersion is observed in the case of GASHSE reflecting the fact that currently domestic gas connections have been extended to only a few of the larger cities and towns in the country. Therefore, as expected, this indicator also shows a high degree of skewness. Other indicators exhibiting high degree of regional concentration are PUCCA and METROAD. At the other extreme, indicators with the least dispersion are CASHV, BANKS, IRRIGATION, PRIMARY, LITRATE and SEXLIT. In particular it is interesting to note the widespread network of commercial bank branches in the country. Banks appear to have followed a policy of regional penetration even perhaps at the expense of profitability. In addition, the relative uniformity of PRIMARY and LITRATE among districts attests to the fact that there has been a commitment to the goal of universal basic education.

It appears from the table of zero-order correlation coefficients (available from authors on request) that INDVAD, BANKS, DOCTORS, HOSPBED, PUCCA, ELECHSE, WATHSE, METROAD and GASHSE are highly intercorrelated with correlation coefficients ranging from 0.70 to 0.75. It is likely, therefore, that they represent some common underlying phenomenon associated with development. This is discussed in a later section.

Correlations between the four agricultural indicators are not very high (except for IRRIGATE and FERTILIZ at 0.75). Nor are the two employ-

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TABLE 1

Summary measures of distribution of indicators at district level

Indicator	Unit	Mean	Standard deviation	Coefficient of variation	Skewness
CASHV	Rs. per capita	544.428	256.871	0.472	0.691
INDVAD	Rs. per capita	106.817	158.739	1.486	3.207
BANKS	No. per 100,000 population	5.517	2.931	0.531	1.774
LIVESTK	Units per capita	0.575	0.371	0.645	3.902
IRRIGATE	%	62.487	33.556	0.537	−0.558
FERTILIZ	%	32.565	28.537	0.876	0.369
TRACTOR	%	12.970	12.816	0.988	1.134
COMMAG	%	79.170	14.822	0.187	−1.735
INDEMP	%	8.976	10.813	1.205	1.953
CAPEMP	%	12.835	18.785	1.464	1.445
PUCCA	%	6.102	11.506	1.886	5.445
WATHSE	%	5.928	6.686	1.128	3.137
ELECHSE	%	13.317	10.619	0.797	1.921
GASHSE	%	1.147	2.718	2.370	4.358
LITRATE	%	17.774	9.282	0.522	1.361
PRIMARY	%	30.763	12.586	0.403	1.605
SECONDARY	%	20.007	13.922	0.696	0.905
COLLEGE	%	2.072	1.312	0.633	1.446
DOCTOR	%	1.118	1.191	1.065	2.632
HOSPBED	No. per 10,000 population	5.093	4.002	0.786	2.010
METROAD	No. per 10,000 population	10.139	17.259	1.702	5.512
UNMETROAD	Miles per 100 sq. miles	11.787	11.481	0.974	−0.778
RAILWAY	Miles per 100 sq. miles	4.526	3.207	0.709	0.763
PASLOAD	No. per 10,000 population	18.583	22.029	1.185	1.827
TELPHON	No. per 1,000 population	6.104	5.367	0.879	2.147
SEXLIT		28.261	13.040	0.461	1.746
SEXENRL		33.520	21.721	0.648	0.708

ment indicators highly correlated at 0.28. Correlation among the education indicators is relatively high. This is also the case with the health and sexual equality indicators. However, there is not much correlation among the transport indicators.

With regard to the income and wealth indicators – CASHV, INDVAD, BANKS, LIVESTK – it is interesting to note that they are not highly correlated with each other (except for the correlation between INDVAD and BANKS of 0.74). However, their correlation with the education, health, housing and sexual equality indicators is quite high.

IV. Techniques for Deriving Composite Indicator

Two types of composite indicators have been derived for development ranking purposes. The first (ZSUM) is based on standardization of the indicators. The second (WEIGHTED FACTOR SCORE) emerges from principal components analysis of the indicators.

Z-SUM

This technique involves the standardization of variables so that each indicator has a distribution with a zero mean and a standard deviation of unity, as follows:

$$Z_{ij} = \frac{X_{ij} - \bar{X}_i}{S_i}$$

where i refers to the indicator (i=1 ....27) and j refers to the district (j=1, ..46). $\bar{X}_i$ is the mean of the ith indicator and S_i the standard deviation.

The composite indicator is then constructed simply by assigning equal weights to all indicators and summing them as follows:

$$Z\ SUM = \sum_{i=1}^{27} Z_{ij}$$

where Z_{ij} is the value of the ith z-score for the jth district.

The resulting distribution of Z-SUM also has a zero mean which provides a reference point for comparing districts with the average. However, the basic defect with this technique is that it attaches equal weight to all the indicators.

A variant of the above type of composite indicator attempts to make

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the distribution of each indicator more closely approximate the normal distribution by first taking natural logarithms of variables, deriving the z-scores and then summing them. This transformation tends to compress the outliers by approximating long tails more closely to the normal curve. The robustness of the results can then be checked by carrying out a rank correlation between the two z-sum indicators.

WEIGHTED FACTOR SCORE

This type of composite indicator is derived after carrying out a principal components analysis on the development indicators and using weights derived from this analysis. Basically, factor analysis in its principal components form is represented by,

$$Z = \Lambda . F,$$

where Z is the 27 x 46 matrix of observations on the 27 indicators for the 46 districts. Λ is the 27 x 3 matrix[2] of factor loadings and F is the 3 x 46 matrix of unobserved factor scores on each of the three factors for each of the 46 districts.

The objective is to determine the factor loading matrix Λ and the factor scores F. The factor loadings are the coefficients that make a linear combination of the indicators and these coefficients are chosen so as to maximize the explained variation in the data by the first factor.

The diagonal elements of $\Lambda'\Lambda$ contain the contribution of the jth factor to the explanation of the unit variance of the N variables Z_i, i.e.

$$\sum_{i=1}^{27} a_{ij}^2 = \lambda_j$$

where λ_j is the eigenvalue of the jth factor.

Also the total variance to be explained is trace R (where R is the correlation matrix) = trace $(\Lambda\Lambda')$ = trace $(\Lambda'\Lambda)$.

The proportion contributed by the jth factors is λ_j/N of the total variance to be explained.

It is clear therefore that the sum of the square of the coefficients down a column of the factor loading matrix is the eigenvalue and also the sum of the squares of the loadings along a row -- known as the communality -- represents the amount of variation in the variable explained by the three factors. It is therefore analogous to R^2 in regression analysis.

[2] The number of factors was constrained to three, firstly, because the objective was to obtain a sufficient degree of clustering of the indicators, and secondly, because the eigenvalue of factors beyond the third factor was relatively small. The latter reason tends to justify the constrained procedure.

Varimax rotation was used in the factor analysis. Quartimax rotation was also used but did not materially change the results.

Since the number of factors has been constrained, the factor scores were obtained in the following manner:

$$(A'A)F = A'Z$$

implying

$$F = (A'A)^{-1}A'Z$$

Finally, the composite indicator is simply the weighted factor score of each district. The weights correspond to the eigenvalue of each factor.

A. Results of Principal Components Analysis

Table 2 displays the factor loading matrix of development indicators with the communality coefficients, eigenvalues and proportion of variation explained. As mentioned earlier, the number of factors has been constrained to three to facilitate their economic interpretation. These three factors explain 63.5 percent of the total variation in the data. A description of each factor is given below.

Factor 1. This factor explains 36.5 percent of the variation. It includes most of the indicators from the housing, health and education sectors. Also included are banks (BANKS), industrial value added per capita (INDVAD) and two indicators of transport sector development, metalled road mileage (METROAD) and PASLOAD, passenger load carrying capacity per capita. The number of telephones per 1,000 population (TELPHON) and female-male literacy ratio (SEXLIT) also fall in this factor. Altogether, factor 1 is interpreted as capturing the effects of modernisation and urbanisation. Of particular significance is that it includes indicators of social and economic infrastructure like water supply, electricity, gas, education and health facilities, roads, telecommunications, banking, etc., which are generally the responsibility of governments in developing countries.

A possible description of the process of development described by factor 1 is that cities and large towns begin to discharge functions of service centres to the rural hinterland. Also, due to agglomeration economies, industry tends to locate in such areas. As a result of the performance of these functions, urban areas acquire a certain dynamism which attracts other services, viz., banking, doctors, etc., to these areas.

Factor 2. The second factor accounts for about 18 percent of the variation and is somewhat more difficult to interpret. Along with factor 3 it captures variation in the magnitude of development indicators not explained

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APPENDIX J
ESTIMATION OF RURAL ELECTRIFICATION COSTS

Appendix J

Estimation of Rural Electrification Costs

For the financial and economic analysis of each customer type presented in Chapter 3, rural electrification (RE) costs were estimated by developing various simplified unit costs. These unit costs were developed early in the study and are based on existing RE practice and not on the lower cost approaches developed later and presented in Chapter 5. The categories for RE cost estimated are: customer, connection, village distribution (distribution transformers and LV lines), and area distribution (HV lines and grid substation). For the customer analysis, the village and area distribution were combined into one average cost called "RE distribution" on the tables in Chapter 3.

Table J-1 presents the financial and economic costs used for the different customer types.

The average RE distribution cost used in Chapter 3 is 6,000 Rs/kw at the point of generation. Individual kw demands are converted to the different supply levels by the following factors: 0.85 to the village distribution transformer, 0.75 to the grid substation, and 0.65 to the generating plant. For example, the RE cost of 6,000 Rs/kw at generation is equivalent to about 4,600 Rs/kw at the distribution transformer. The RE distribution cost is based on a number of unit costs:

1. Grid substation: 1,000 Rs/kva with 0.8 power factor.

2. HT distribution line: 100,000 Rs/km.

3. Distribution transformers: 500 Rs/kva with 0.8 power factor.

4. LT distribution line: 70,000 Rs/km and 7 meters per customer.

The average cost was estimated based on the village case presented in Appendix G where the village has 219 customers (including tubewells) with a peak demand at generation of 86.6 kw. The length of HV distribution line used is about 2.17 km. The breakdown of the 6,000 Rs/kw (at generation) cost is:

1. Grid substation: (1000/0.8) * (0.75/0.65) = 1442 Rs.

2. HT distribution line: (100,000 * 2.17km)/86.6kw = 2502 Rs.

3. Distribution transformers: (500/0.8) * (0.85/0.65) = 817 Rs.

4. LT distribution line: (70,000*0.007 * 219 customers)/86.6 kw = 1239 Rs.

It should be noted that these costs are approximations. This average RE distribution cost is intended to be only indicative of actual costs.

The economic costs for RE distribution are taken to be 70 percent of the above financial costs.

Table J-1

Financial and Economic Customer and Connection Costs

User Types	Financial Analysis: Internal Wiring	Financial Analysis: Service Connection	Financial Analysis: Unofficial Initial Cost
Low Income Household	250	1200	500
Ave Income Household	500	1200	750
High Income Household	1000	1200	1000
Tubewell	500	10250 *	10000
Rural Industry	500	15000 **	10000
Commercial	500	1200	500

User Types	Economic Analysis: Internal Wiring	Economic Analysis: Service Connection ***
Low Income Household	250	840
Ave Income Household	500	840
High Income Household	1000	840
Tubewell	500	7175
Rural Industry	500	10500
Commercial	500	840

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* The customer charge for connection is after the 30,000 Rs. connection subsidy. The total cost is based on 4000 Rs for service connection, 22250 Rs. for the distribution transformer, and 14000 Rs. for 0.2 km of LT line.

** This cost consists of 4000 Rs. for the service connection, 6000 Rs. for extra LT line, 5000 Rs. for the transformer.

*** Economic costs are 70 percent of financial costs.

APPENDIX K
STUDY SCOPE OF WORK

Appendix K

Study Scope of Work

1. Definitions of Rural Electrification for the Master Plan Revision

   1.1 Definition (for purposes of identification) of rural electrification.

   1.2 Definition (for purposes of identification) of rural areas for the purposes of rural electrification;

2. Selection Methodology and Establishment of Criteria

   2:1 Methodology for use of economic, social and financial criteria in selecting areas to be electrified and policies regarding connections to be made, giving due consideration to established constraints including adiministrative practices and geographical distribution, as well as comparison and correlation of use of these criteria with physical criteria (eg: distance to village, population, number of domestic and commercial consumers, numbers of irrigation tubewells, etc.).

   2.2 Establishment of a set of alternative composite criteria based on the above. This set of ceritaria are to be translated into physical terms by backward linkage to the analysis of social, economic, and practicable in Pakistan and easily understanable and useable by Engineers/Technicians in the field, as well as by public representatives and civil servants all of whom may be involved in village and/or connection selection, monitoring, and compliance.

3. Technical Aspects

   3.1 Identification and choice of the appropriate technical options (single or three phase service, distribution equipment, distribution networks, service reliability) to be used in Rural Electrification intensification and expansion;

   3.2 Identification and choice of generation options: isolated generation (diesel, hydro, coal, etc.) or central grid connection, by which a given area or group of areas are to be electrified.

   3.3 Establishment of economically rational relationships among GOP's Rural Electrification, other power transmission and distribution system intensification and expansion, energy loss reduction, and power generation expansion priorities and plans as envisaged in the seventh plan.

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4. Designation of Institutional Responsibility

4.1 Designation of the executing agency for the GOP's Rural Electrification Program, as well as identification of possible operator(s) of existing and new Rural Electrification Systems on behalf of the government; and reforms and actions to be taken.

5. Subsidy, Pricing and Connection Policies

5.1 Identification of the level of subsides (including methodology used, data requirements, and formats for estimating subsidy calculations) required for, and the tariff issues related to, the design, construction, operation and maintenance of existing and new Rural Electrification Systems.

5.2 Analysis of the willingness of the rural population, tubewell users and other productive use consumers to pay the cost of obtaining service, the cost of wiring their homes, business or tubewell, and the cost of continuing service;

5.3 Identification of implementable, cost recoverable approaches to improve intensification of connections through measures such as provisions for extended payments for the rural poor to finance the cost of wiring their homes and obtaining electric services, and provisions for establishment of life-line minimum tariffs to permit access of the rural poor to electric service; methods to improve revenue collection.

5.4 Simplified procedures for customers applying and being considered for electric service, including ongoing customer service improvements.

6. Data Basis

6.1 Clear presentation of the data basis for the selection criteria, including listing of the key economic, technical, physical, social and financial parameters and assumptions;

6.2 Proposals for Improving the Data Base.

6.3 Description of the key data refinements and additional studies required for updating of this rural electrification master plan;

7. Application Procedures

7.1 Procedures for implementing the master plan by operational and field entities identified in 4.1 above.

7.2 Procedures for utilizing the master plan for developing implementation plans for projects that might be considered for financing by international donor agencies, including procedures for specifi work orders is appropriate. Discuss the capabilities and need for maximizing procurement of material and equipment manufactured in whole or part in Pakistan vis a vis the requirement for rural electrification; and

7.3 Initial application of the criteria through at least one sample area distribution planning application in each province. The sample areas chosen shall include sufficient villages to demonstrate the empirical validity of the criteria.

APPENDIX L
STUDIES REQUIRED FOR RURAL ELECTRIFICATION PLANNING

Appendix L

Studies Required for Rural Electrification Planning

1. Introduction

Generally, data and studies are required for rural electrification planning to provide the bases for (1) allocating funds among provinces and districts for the construction of distribution systems; (2) selection of specific villages for new electrification; (3) for selection of villages for "backfilling"; (4) establishment of new policies relating to tariffs, connection charges, and other issues; and (5) implementing the process of continuing monitoring and evaluation. A substantial effort is required in bringing all of the data sources together to create a meaningful and useful set of data bases for RE planning, as described in Appendix M.

2. Phases of Data Collection

The collection of primary data, and the collation of existing secondary data, should occur over time such that the data that are required for each successive phase of the electrification program are available when needed, avoiding delays in the electrification process. With limited resources, these efforts should be well planned from the outset to avoid collecting unnecessary data and incurring unnecessary expenses.

During the first few months of this RE plan, basic data on every settlement can be collected that include the numbers of households, small industries and tubewells, and the distances from the nearest 11 kV line. These data will then be used in the selection of the settlements/villages that are to be electrified during the first year. Since much of these data are already available, it should be a relatively straightforward task to collate and present them in the appropriate format.

The next phase of data collection proposed would be to carry out a survey in one village in every district or tehsil, to enumerate kerosene and electricity usage, and to estimate the distributions of income. The purpose of these surveys would be to determine the differences in village characteristics within and among districts. These surveys should then be repeated, in the same villages and households, in subsequent years to determine changes in usage patterns.

The collection of data should always remain flexible enough to include new data requirements as they become apparent, planned well enough to avoid unnecessary costs where possible, and at the same time be coordinated with the phased approach to planning and electrification as discussed in Chapters 4 and 6.

3. Recommended Studies and Projects for Immediate Implementation

- Data Collection Plan

The first task in assembling a set of data bases is to establish an overall, detailed but flexible data collection plan that is based on (1) existing data bases and sources of non-computerized sources of data, (2) needs for decision-making in allocating budgets, electrifying villages, and establishing new policies, and (3) needs for monitoring and evaluation on a continuing basis. The major steps in this process are described in this chapter.

- Nationwide Village/Settlement Sample Survey

In accordance with the phased data collection process described above, basic data are required for all of the villages/settlements in Pakistan, to facilitate decision-making in the first years of this plan. These data should include the numbers of tubewells, numbers of rural industries, numbers of households and their distribution of income, numbers of commercial and other consumers, distance to the nearest feeder (as integrated with the mapping effort), electrification status, and (if electrified) the present usage patterns of electricity.

Many of these data are already available in various forms (see section 6.5). This will reduce the amount of primary data collection required, and will establish the beginnings of the village data base (see Appendix M).

- Studies of Connection Financing

One of the primary impediments to increased growth in the numbers of household consumers is the high connection cost. In other developing countries, low-interest loans are available for low income households to make electricity available to all income groups. A study is required to determine the number of households, that are not now capable of paying this first cost, and that would connect to the system if such loans were available.

- Tariff Study

A thorough study is required to establish equitable tariffs that are also financially and economically viable (see chapter 3), for all customer groups, and to implement a system by which tariffs are periodically reviewed and updated. These tariff computations should be linked to the implementation of cost-saving strategies that are discussed in chapter 5.

- Physical Fuel Use Studies

Additional studies are required to determine the number of kerosene lamps displaced by one bulb, wattage of bulbs installed by low and high income users, and the amount of kerosene displaced in volumetric terms.

Another dimension of these studies is the laboratory-scale examination of the hourly consumption of kerosene, by most popular lamp types, and under varying conditions: age of wick, high or low setting, draftiness of environment, and others (see Appendix C).

- Ex-Post Electrification Impact Studies

A fundamental set of data that are not available in Pakistan relate to the impact of electrification on overall energy demand, the distribution of income, and general economic development, that are directly attributable to electrification. Without these data, the total economic benefits of electrification will be underestimated.

- Energy Demand and Load Research

Research on daily and seasonal load durations for individual connections is also required, for all customer classes. It has been found in our case studies (see Chapter 3) that the coincidence between peak demand by the customer and for the RE system as a whole has a substantial impact on the economic costs of delivering power; reducing this coincidence can greatly reduce the overall cost. It is therefore vital that the actual coincidence factors be studied and clearly understood, for all tariff classes, in order to take advantage of these potential cost savings.

A time series study of rural domestic, small industrial, tubewell, and commercial consumer electrical energy usage, starting from year of electrification for as long as a time series is available, is required.

These data are needed for each income or wealth category of households, and other customer types, in a manner such that they are statistically representative of villages from all four provinces. They should include the rate of growth of demand within households and other connections, and the rate of growth of connections. They should also include the accuracy of rural billing records, based, for example, on a comparison of grid station electricity flow records with line metering records.

The incidence of "multiple household" connections, and the frequencies of village-industrial (for example, flour mills) and village-commercial (that is, small shops and the like) as adjuncts to household connections need to be examined closely.

- Tubewell Studies

There are several issues that are focused on tubewells, especially in view of the unfavorable economics in this application of electric power (see Chapter 3). Can electric tubewells be economically viable if they are operated more efficiently? If tubewells are operated only during non-peak hours, will that enhance them financially from WAPDA's perspective? Should the connection subsidies and tariffs be changed, and if so, by how much?

Given the popularity of electric tubewells, and the benefits derived from them that are difficult to quantify (such as the lower requirements of management resources, especially among small farmers), these issues must be addressed carefully and in depth.

- Mapping

An important issue in the village data set will be the location of villages, grid stations, and feeders. While this task must be done on a continuing basis, it must be started as soon as possible, since much of the RE planning effort will require these data.

As more villages are electrified, and more grid stations and feeders are constructed, more villages will be closer to connection points. This cost reduction benefit can only be captured if new electrification is tracked on a locational basis.

This task will involve the establishment of a nationwide computerized data system that, with frequent updating, will include map coordinates of all settlements, grid stations, and feeders, along with the electrification status of settlements, capacities and available capacities of the grid stations and feeders.

- Complementary Investments Studies

As discussed in Chapters 3 and 4, rural electricity has aspects of both an individual service and an investment that complements others. As a complementary investment it will be important to measure the extent that other development infrastructure and services are available in an area under RE consideration. It is therefore necessary to adjust the 27 measures of development potential that are listed in Ref 45 and discussed in Chapter 4.

- Completion and Integration of PTAT and WAPDA Data Bases

As described in Appendix M, there are two computerized data bases now under development that must be completed. The first is the WAPDA Master File, that contains meter records from every connection. This data base is presently under development, since several of the AEB's are undergoing computerization.

The data base developed by PTAT and USAID is still in the data collection stage. Both of these data bases are vital to RE planning, and should be integrated, along with the village/settlement survey data, into the village data base (see Appendix M). They are described below in this chapter, and should be completed at the earliest possible date.

- Interim Technical Standards and Supply Alternatives

A study is required to establish a set of interim technical standards that can be implemented quickly, in order to achieve short-term cost savings in the distribution of rural electricity (see Chapter 5 and technical Appendices).

4. Long-term Monitoring and Evaluation

- Statistical Fuel and Electricity Consumption Surveys

These more extensive than the short-term efforts required for understanding energy demand and for load research. They represent the continuation of the phased approach to data collection and analysis as discussed in section 6.3.1.

The most difficult method of data collection is from surveys, since they tend to be time consuming, expensive, and require widely varying skills in implementation. Village surveys will be necessary, however, on a continuing basis to obtain the detailed data that are required for RE planning.

These surveys should include energy consumption and expenditures, income or wealth measures, willingness and ability to pay for electricity, and through analysis of the data, the impacts of RE on employment and income distribution. They must also include the cultural aspects of energy consumption among households, in order that the true social impacts of electrification may be better understood. These studies will help to establish socio-economic weights for use in economic analyses of RE.

Many of these cultural variables are lost in the calculus of RE, since cultural aspects are often taken for granted among Pakistanis professionals, and frequently misunderstood among expatriates. These oversights can lead to misinterpretation of data and erroneous conclusions.

Ideally, every village that is considered for eventual electrification should be surveyed to this level of detail. In Pakistan, this should in fact include all settlements. This is impractical, at least in the opening phases of the planning effort. A viable compromise must be reached between the need for accurate data and scarcity of resources for data collection. The compromise should take the form of a cluster type of sample, whereby the data from several villages represent those from all of the villages in a particular district or tehsil. At a minimum, households should be completely surveyed in one electrified village and one non-electrified village, in every district or tehsil.

In addition to household surveys, data concerning the villages themselves should be collected: local market and economic prices of fuels and appliances, and the costs and revenues involved in the delivery of electric power to a specific location.

The data obtained from these villages may then be used to characterize the other villages in that district, in terms of energy demand. They should therefore be large enough in each village to be statistically significant.

- Impacts of Electrification on Small Farms and Industry

It is probable that electrification of farms and rural industries will result in increases in productivity, due to both the increased quality and convenience of electricity when compared to alternatives, and to increased hours of production from improved lighting conditions. It may also lead to increased employment, for the same reasons.

It is important in the evaluation of RE to understand these potential benefits, so as to avoid undervaluing the benefits derived.

- Technical Standards Evaluation

New technical standards should be developed, to update those discussed in section 5.3.B above, on an ongoing basis, to ensure that the least cost procedures are used without sacrificing quality of service.

- Tariff Studies

The studies described in the previous section must be updated on a continuing basis, on the ways in which customer fees (connection charges, FAC, and tariffs) relate to the costs of generation, transmission, and distribution, implicit subsidies, and the transfer payments within WAPDA and between WAPDA and other agencies.

- Updating of PTAT, WAPDA, and Mapping Data Bases

The WAPDA Master File, that contains meter records from every connection, must be updated monthly, and summary data bases generated as needed for RE planning. The data base developed by PTAT and USAID, and the Mapping data base, should be updated annually. After updating, summary data should be extracted from this file for use in RE planning. All of these must be integrated, along with the survey data described in above.

5. Summary of Required Studies

The two sections above describe studies that are required for immediate implementation, and those that must be implemented on an ongoing basis, to provide for continuing monitoring and evaluation. These are summarized in the following Table L-1.

The first task among the projects for immediate implementation is to establish a detailed data collection plan. This will provide a schedule of data collection activities to allow for the coordination of resource allocation (manpower and budgets). It should be completed immediately by the new central REO.

Several of the immediate tasks involve overlapping geographic efforts: the nationwide village/settlement sample survey, ex-post electrification studies, and energy demand and load research. All of these involve extensive (and in some cases intensive) data collection, from widely dispersed locations. They all focus on the customer level as the unit of analysis, and the data collected will be useful in building the village data base (see next section), in estimating the benefits of electrification (see chapter 3), and in establishing policies.

Table L-1 Required Studies

For Immediate Implementation:

- Data Collection Plan
- Nationwide Village/Settlement Sample Survey
- Studies of Connection Financing
- Tariff Study
- Physical Fuel Use Studies
- Ex-Post Electrification Impact Studies
- Energy Demand and Load Research
- Tubewell Studies
- Mapping
- Complementary Investments Studies
- Completion and Integration of PTAT and WAPDA Data Bases
- Interim Technical Standards and Supply Alternatives

For Long-Term Monitoring and Evaluation:

- Statistical Fuel and Electricity Consumption Surveys
- Impacts of Electrification on Small Farms and Industry
- Technical Standards Evaluation
- Tariff Studies
- Updating of PTAT, WAPDA, and Mapping Data Bases

The village/settlement survey, ex-post studies, demand and load research, the mapping task and the completion of the PTAT and WAPDA data bases, should be completed within the next six months to allow for the rapid establishment of the first village data base. These tasks should be designed by the central REO and implemented by the RE Offices in the AEB's.

Setting interim technical standards should result in immediate benefits through cost reductions (see chapter 5). These should be implemented within the next six months, by the central REO.

Tariff, tubewell, and connection financing studies all relate to customer payments. It is logical for them to be conducted as linked efforts, with the connection and tubewell studies added to the tariff study. All of these tasks are related to policy options. They should be implemented within the next twelve months by the central REO.

The remaining tasks for immediate implementation, studies on physical fuel use and complementary investments, do not have as high priorities as those listed above, but they should be started during the first year of this plan. The physical fuel use studies should be conducted by the central REO, and the complementary investment studies, being regional, should be implemented by the RE Offices in the AEB's.

Three of the projects for long-term monitoring and evaluation, statistical surveys, impacts of electrification, and tariff studies involve periodic (ideally annual) field data collection. Teams should be organized by the REO's in the AEB's to collect the required data simultaneously. These data will at first be analyzed at the central REO, until such time that the computer programs are developed and distributed to the AEB's.

The WAPDA Master Files are updated monthly by the AEB's; the summaries of these data bases are required for RE planning only on an annual basis, so only annual updates from these data bases are required. However, the creation of new summary files will be required every month. These data will be collated by the AEB's and passed on to the central REO. The Mapping and PTAT data bases are updated yearly, by the AEB's. All of these will serve to update the village data base every year.

Based on revisions of labor and equipment costs, and on the development of new equipment manufacturing technology, technical standards should be updated every year by the central REO. This will ensure that the system is maintained using least-cost standards and procedures.

Development of the Least Cost Rural Electrification Area Expansion Plan

The least cost Rural Electrification Area Expansion Plans shall indicate the optimized transmission, grid station and distribution network configurations on maps to scale 1:50,000 and shall include as a minimum the following :

- o Identification of all villages in the census lists on maps
- o Preparation of as-built maps of existing distribution system based on available data from WAPDA subdivisions or distribution mapping
- o Limited field surveys to determine parameters for the load forecast
- o Preparation of energy and demand forecasts by individual villages and the areas as a whole treating the tubewell demand on special basis
- o Determine the best integrated solution for transmission, grid stations and distribution expansion including determine action of the most suitable choice of primary voltage and phase options
- o Determine to most suitable choice of distribution equipment and materials
- o Prepare the design of most suitable network configurations for the HT and LT networks
- o Prepare designs for a selected number of villages of LT distribution
- o Prepare estimates of capital investment, present worth of benefits and data by villages and feeders in accordance with the requirements of the village data base
- o Show the network configuration for the HT networks to scale scale 1:5000.

APPENDIX M

DATA BASE REQUIREMENTS FOR RURAL ELECTRIFICATION PLANNING

Appendix M

Data Base Requirements for Rural Electrification Planning

1: Required Data Bases

One of the objectives of the studies described in Appendix L is to develop data bases for RE planning, as well as for long term monitoring and evaluation. This section describes the data bases that will, in part, result from those studies, and sources of existing data.

1.1 The Village Data Base

The main purpose of the village data base is to provide an analysis tool for evaluating villages in terms of costs and benefits, for eventual electrification. This should be a set of data bases, some of which contain data for all settlements, others containing statistically representative data.

One of the difficulties of collecting data from rural areas is in the definition of the "unit of analysis." This "unit" is the focus of decision-making, and is crucial to effective data analysis. In the case of RE, this unit is the "settlement," but this term must be clearly defined and consistently used, to include all centers of rural population. The traditional usage of the term is ambiguous, referring to a "sub-village" thereby excluding central villages. A more appropriate definition, as discussed in Chapter 1, would be any population center with a predetermined number of people or households.

These data should be collected at least twice, preferably after a one year interval, in order to estimate the growth rates in the numbers of connections and the load growth for each connection type, in electrified villages. It will also allow for the estimation of changes in demand of other energy sources for which electricity is a substitute such as kerosene. See the section in this chapter on data management for further details on the uses of these data.

Another important reason for follow-up data collection is to assess the impact of electrification on the economic growth and distribution of income within villages resulting from electrification. This will improve the accuracy of benefit measurements from RE for those villages that are still not electrified. Toward this end, the industrial and agricultural production levels should be measured, for all villages. Therefore, data must be collected from villages before and after electrification.

1:2 The District Data Base

There are several alternatives under consideration for allocating RE resources among districts (see chapter 4): Many of the variables required for these data bases can be generated as aggregates from the village data bases: numbers and sizes of connected and non-connected households, population, and villages; agricultural and industrial development:

One of the approaches discussed in Chapter 4 is based on 27 indicators of development (ref 45): These indicators must be updated annually, for all districts, and maintained in a data base for analysis:

1:3 The Provincial Data Base

The allocation of resources to the four provinces and FATA will be a function of rural and total population, number of villages, households, and population that are electrified and not electrified, and the average cost of village electrification: These data can be derived as aggregates from the district data bases: If the village and district data bases are maintained, no further data collection should be required:

2: Sources and Status of Existing Data

The most obvious and comprehensive source of data is from WAPDA itself, where two substantial sources of computerized data are under development: One is the WAPDA/USAID Power Distribution Program, Rural Electrification Project data base, developed at PTAT, which has data on the village and subvillage level:

WAPDA also maintains data bases, among the AEB's that are now computerized, containing complete meter data for all connections: In those AEB's that are not computerized, the SDO's often maintain records on all connections; these data may be computerized, but at a considerable level of effort:

The provincial governments are another potential source of data: At least two provinces, Sind and Punjab, have collected data concerning the electrification status of settlements:

2:1 The PTAT Data Base

This computerized data base includes general demographic data, including village location in terms of district, tehsil, AEB, and hadbast; Census ID code, village or subvillage name, the number of sub-villages in a given village (all of which are listed), a map reference (but no coordinates), population, and numbers of households:

It also includes data related to electric power, including the year that the village was electrified (if applicable), status of electrification (if "properly electrified", not electrified, or "not properly electrified"), the identification of the nearest grid station and feeder, distance to the nearest existing feeder in km (if the village is already electrified, this distance is zero), and the number of household, commercial, tubewell, and industrial connections: This data base can also be associated with another existing data base at PTAT, that has information on feeder and grid station sizes:

The data contained in these data bases are vital to the village RE planning data base, and should therefore be completed and updated annually:

2:2 WAPDA Master Files

This data base is really a set of data bases that is maintained by the individual AEB's: The computer program that is used to create and maintain these data sets are written by the Computer Center in WAPDA Lahore, and are therefore common to all of the computerized the AEB's:

Only four of the eight AEB's are now completely computerized; the Peshawar AEB is partially computerized: Efforts are continuing to computerize all AEB's:

Unfortunately, these data do not seem to have the same fields for location as does the village data set at PTAT (tehsil, district, etc:): In the WAPDA data base, they are identified only by the sub-division and the village name:

This data base is necessary for the building and maintenance of the village RE planning data base, since it contains data on consumption of electric power for individual connections:

2:3 SDO Meter Data

Among the AEB's that are not yet computerized, billing and metering data must be collected from Sub-Division Offices in the field: At least some of these offices maintain data for each connection, concerning the tariff class and meter readings, by month, for several years: These can be used to fill in many of the gaps where computerized data are not yet available:

2:4 Provincial Data

The provincial governments of Sind and Punjab have collected data concerning settlements: In Punjab, a list was compiled in 1987 by Power and Irrigation, of 64 randomly selected electrified census villages: It includes the names of all non-electrified settlements in those villages, distances to their nearest 11 kV lines, and the costs of electrification of each settlement: The overall average number of non-electrified settlements in electrified villages was 2:25:

The Sind Bureau of Statistics, Planning and Development Department, has published the results of a survey of rural settlements in 1986 (Ref 163 and 164): It includes the electrification status of each settlement, and the distances to the nearest high tension line for those that were not yet electrified: The data are in computerized format:

PAKISTAN RURAL ELECTRIFICATION MASTER PLAN REVISION

TECHNICAL ANNEXES

TABLE T1-16
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lbs/sq.ft
VERTICAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wase														
	a Structures	27027	28395	28621	26460	29460	18919	15120	15060	10554	12583	16376	20327	36271	45736
	b Hardware & Foundation	1030	1803	9109	11830	11830	1030	1440	1440	1803	1803	3576	3573	9084	9084
	c Total	28057	30198	37730	38290	41290	19949	16560	16500	12357	14385	19955	23906	45355	54820
4	Chafer														
	a Structures	27027	28395	28621	28180	29460	18919	15120	15060	10976	12583	16627	20533	37720	47616
	b Hardware & Foundation	1030	1803	9109	12599	11830	1030	1440	1440	1875	1803	3633	3633	9446	9446
	c Total	28057	30198	37730	40779	41290	19949	16560	16500	12851	14385	20260	24271	47166	57072

TABLE T1-17
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR COMPOSITE LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 8 lbs/sq.ft
HORIZONTAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wasp + Rabbit														
	a Structures	62294	64139	44009	67288	34763	24952	31193	31069	25838	20994	19302	18127	28578	36082
	b Hardware & Foundation	16579	28450	25373	54496	25287	9487	20754	20754	30834	21015	29466	22293	49998	49998
	c Total	78873	92589	69382	121784	60050	34438	51946	51823	56672	42010	48768	40420	78576	86080
4	Chafer + Dog														
	a Structures	85504	87522	60364	92319	47607	34160	42759	42590	35448	28914	26360	22740	28578	36082
	b Hardware & Foundation	22756	38822	34802	74769	34631	12987	28450	28450	42302	28943	40240	27967	49998	49998
	c Total	108259	126344	95166	167088	82238	47147	71209	71039	77750	57856	66600	50707	78576	86080

TABLE T1-18
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR COMPOSITE LINES PER km
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lbs/sq ft
VERTICAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Gnat + Squirrel	329	148	328	164	164	328	164	164	121	121	-	-	-	-
2	Ant + Goper	318	131	328	164	164	328	164	164	95	98	-	-	-	-
3	Wasp + Rabbit	227	131	316	150	164	328	164	164	49	53	-	-	-	-
4	Chafer + Dog	165	99	230	109	164	288	134	134	41	46	-	-	-	-
	NUMBER OF STRUCTURES PER km														
1	Gnat + Squirrel	10.00	22.16	10.00	20.00	20.00	10.00	20.00	20.00	25.04	25.04	0.00	0.00	0.00	0.00
2	Ant + Goper	10.31	25.04	10.00	20.00	20.00	10.00	20.00	20.00	33.47	33.47	0.00	0.00	0.00	0.00
3	Wasp + Rabbit	14.45	25.04	10.38	21.87	20.00	10.00	20.00	20.00	33.47	33.47	0.00	0.00	0.00	0.00
4	Chafer + Dog	19.83	33.13	14.26	30.09	20.00	11.29	24.48	24.48	36.04	33.47	0.00	0.00	0.00	0.00
	UNIT COSTS OF CONSTRUCTION (Rs.)														
1	Structure	3730	2268	3717	2646	2946	2646	1512	1506	843	1005	653	818	575	726
2	Hardware & Foundation	851	851	1987	1987	1987	851	851	851	851	851	851	851	851	851
	COST OF CONSTRUCTION (Rs.)														
1	Gnat + Squirrel														
a	Structures	37240	50259	37170	52920	58920	26460	30240	30120	21109	25165	0	0	0	
b	Hardware & Foundation	8510	18858	19870	39740	39740	8510	17020	17020	21309	21309	0	0	0	0
c	Total	45810	69117	57040	92660	98660	34970	47260	47140	42418	46474	0	0	0	0
2	Ant + Goper														
a	Structures	28972	56791	37170	52920	58920	26460	30240	30120	28415	28667	0	0	0	0
b	Hardware & Foundation	9774	21309	19870	39740	39740	8510	17020	17020	28433	28433	0	0	0	0
c	Total	47746	78100	57040	92660	98660	34970	47260	47140	56848	57120	0	0	0	0

TABLE T1-18
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR COMPOSITE LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lbs/sq.ft
VERTICAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wasp + Rabbit														
	a Structures	54621	56791	38582	57868	58920	26460	30240	30120	28215	33637	0	0	0	0
	b Hardware & Foundation	12297	21309	20625	43456	39740	8510	17020	17020	28483	28483	0	0	0	0
	c Total	66918	78100	59208	101324	98660	34970	47260	47140	56698	62120	0	0	0	0
4	Chafer + Dog														
	a Structures	75146	75139	53004	79618	58920	30138	37014	36867	30382	33637	0	0	0	0
	b Hardware & Foundation	16918	28194	28335	59789	39740	9693	20832	20832	30670	28483	0	0	0	0
	c Total	92064	103332	81339	139407	98660	39831	57846	57699	61052	62120	0	0	0	0

LIST OF TECHNICAL ANNEXES

ANNEX	T1	DESIGN STUDIES OF POLE OPTIONS
	T2	DESIGN STUDIES OF CONDUCTOR SIZES
	T3	DESIGN STUDIES OF DISTRIBUTION TRANSFORMERS
	T4	COST ESTIMATES OF DISTRIBUTION MATERIAL AND CONSTRUCTION
	T5	STANDARD, SPECIFICATIONS AND COST OPTIMIZATION. CASE STUDIES
	T6	SYSTEM APPLICATIONS FOR TECHNICAL OPTIONS. CASE STUDIES

ANNEX T1
DESIGN STUDIES OF POLE OPTIONS

ANNEX T-1

DESIGN STUDIES OF POLE OPTIONS

1 SCOPE

A detailed design study of fourteen distribution pole options was carried out under this project. The study is entitled, "Design Study of Distribution Pole Options". The fourteen options include 2 wood poles to ANSI standard, 3 steel lattice and 9 prestressed concrete poles.

2 POLE TYPES

The fourteen poles are as under.

Pole 1: Wood pole to ANSI - class 7 for HT, 35 ft. height, 203 kg weight.

2: Wood pole to ANSI - class 9 for LT, 30 ft. height, 141 kg weight.

3: WAPDA Standard HT and composite line steel lattice pole, 34.66 ft. height, 203 kg. weight.

4: WAPDA Standard LT line steel lattice pole, 31.17 ft height, 136 kg weight.

5: PTAT designed shortened WAPDA HT steel lattice pole, 31.17 ft height, 151 kg weight.

6: WAPDA Standard HT and composite line prestressed concrete pole, 36 ft height, 1079 kg weight.

7: WAPDA Standard LT prestressed concrete pole, 31.17 ft. height, 696 kg weight.

8: PTAT designed shortened WAPDA HT prestressed concrete pole, 31.17 ft. height, 700 kg weight.

9: Low cost prestressed concrete pole, 29.5 ft. height, 391 kg weight.

10. Low cost prestressed concrete pole, 29.5 ft. height, 470 kg weight.

11: Low cost prestressed concrete pole, 26.2 ft. height, 317 kg weight.

12: Low cost prestressed concrete pole, 26.2 ft. height, 364 kg weight.

13: Low cost prestressed concrete pole, 24.6 ft. height, 2
kg weight.

14: Low cost prestressed concrete pole, 24.6 ft. height, 3
kg weight.

The results of the Detailed Design Study are summarised in tabl
T1-1 to T1-18.

Using various conductor combinations, for three phase and sing
phase HT, LT and composite lines in vertical and horizont
formations, maximum permissible spans by pole strength we
calculated for all the fourteen poles. Similarly, allowab
spans, with reference to sag-tension calculations, we
calculated. Based on these two methods, the lowest of t
calculated spans were selected as the recommended spans wi
reference to both pole strength and sag-tension.

Allowable and recommended spans have been summarised for thr
phase HT lines (table T1-1, T1-2), single phase HT lines (tab
T1-3, T1-4), three phase LT lines (table T1-5, T1-6) and thr
phase composite lines (table T1-7, T1-8), for wind pressure
lbs/sq. ft. and 15 feet ground clearance.

3 COST COMPARISONS

Cost comparisons of pole options for different conductor and li
combinations were made. Detailed analysis is given in the Desi
Study of Pole Options. A summary of results is given in tabl
T1-9 to T1-18 for different types of lines.

4 CONCLUSIONS

The following conclusions can be drawn from the pole study:

- WAPDA should immediately stop procurement of steel latti
structures for HT, LT and composite lines.

- The existing 36 ft prestressed concrete pole should be us
for composite line only.

- The six light weight prestressed concrete poles offer the mo
economical line construction and should be introduced in rur
electrification for both HT and LT lines, without any delay.

- The capacity of the existing WAPDA and private sector po
plants should be increased to meet WAPDA's total requiremen
of low cost distribution poles.

ANNEX T-1
DESIGN STUDIES OF POLE OPTIONS
LIST OF TABLES

Table T1-1 : Allowable spans with reference to Sag-tension calculations for three phase HT lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs/sq.ft.

2 : Recommended spans with reference to pole strength and Sag-tension calculations for three phase HT lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs/sq.ft.

3 : Allowable spans with reference to Sag-tension calculations for single phase HT lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs./sq.ft.

4 : Recommended spans with reference to pole strength and Sag-tension calculations for single phase HT lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs./sq.ft.

5 : Allowable spans with reference to Sag-tension calculations for three phase LT lines for different pole options. Ground clearance 15 ft. Wind pressure = 8 lbs./sq.ft.

6 : Recommended spans with reference to Sag-tension calculations and pole strength for three phase LT lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs/sq.ft.

7 : Allowable spans with reference to Sag-tension calculations for three phase composite lines for different pole options. Ground clearance : 15 ft. Wind Pressure = 8 lbs/sq.ft.

8 : Recommended spans with reference to Sag-tension calculations and pole strength for three phase composite lines for different pole options. Ground clearance : 15 ft. Wind pressure = 8 lbs./sq.ft.

9 : Cost comparison of different pole options for three phase HT lines per km based on maximum allowable span lengths and factor of safety 2.5 Wind pressure = 10.2 lbs/sq.ft.

10 : Cost comparison of different pole options for single phase HT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 10.2 lbs./sq.ft.

ANNEX - T1
DESIGN STUDIES OF POLE OPTIONS
LIST OF TABLES

Table T1-11: Cost comparison of different pole options for three phase HT lines per km based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft.

12: Cost comparison of different pole options for single phase HT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft.

13: Cost comparison of different pole options for three phase LT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8lbs/sq.ft. horizontal formation

14: Cost comparison of different pole options for three phase LT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft. vertical formation

15: Cost comparison of different pole options for single phase LT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft.horizontal formation

16: Cost comparison of different pole options for single phase LT lines per km.based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft. vertical formation

17: Cost comparison of different pole options for composite lines per km. based on maximum allowable span lengths and factor of safety 2.5 wind pressure = 8 lbs/sq.ft. horizontal formation

18: Cost comparison of different pole options for composite lines per km. based on maximum allowable span lengths and factor for safety 2.5 wind pressure = 8 lbs/sq.ft. vertical formation

TABLE T1-1
ALLOWABLE SPANS WITH REFERENCE TO SAG-TENSION CALCULATIONS
FOR THREE PHASE HT LINES FOR DIFFERENT POLE OPTIONS.
GROUND CLEARANCE : 15 FT. WIND PRESSURE = 8.00 LBS. /SQ FT.

NO.	DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)			PRESTRESSED CONCRETE (FT)								
			35'	30'	WAPDA 34.66'	WAPDA 31.17'	PTAT 31.17'	WAPDA 36'	WAPDA 31.17'	PTAT 31.17'	LCP 29.5'(1)	LCP 29.5(2)	LCP 26.2	LCP 26.2'	LCP 27.6'	LCP 27.6'
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Mole	2	656	525	656	590	590	656	590	590	525		361		328	
		2.5	656	525	656	590	590	656	590	590	525		361		328	
2.	Squirrel	2	689	558	689	558	558	754	558	558	492		394		328	
		2.5	689	558	589	558	558	754	558	558	492		394		328	
3.	Gopher	2	722	558	722	623	623	722	608	608	422		394		295	
		2.5	722	558	722	623	623	722	623	623	558		394		295	
4.	Weasel	2	689	525	689	590	590	689	590	590	525	525	304	390	295	
		2.5	689	525	689	590	590	689	590	590	525	525	394	394	295	
5.	Rabbit	2	656	492	656	574	574	656	574	574	492	492	328	328	295	
		2.5	656	492	656	574	574	656	574	574	492	492	328	328	295	
6.	Dog	2	656	525	656	525	525	656	525	525	492	492	394	394	295	332
		2.5	656	525	656	525	525	656	525	525	492	492	394	394	295	332
7.	Pelican	2	590	459	590	525	525	656	525	525	459	459	328	328	262	262
		2.5	590	459	590	525	525	656	525	525	459	459	328	328	262	262
8.	Panther	2	772	525	722	590	590	722	590	590	525	525	394	394	328	328
		2.5	772	525	722	590	590	722	590	590	525	525	394	394	328	328
9.	Osprey	2	590	459	590	525	525	656	525	525	459	459	328	328	262	262
		2.5	590	459	590	525	525	656	525	525	459	459	328	328	262	262

FS = Factor of Safety

TABLE T1-2

RECOMMENDED SPANS WITH REFERENCE TO POLE STRENGTH AND SAG TENSION CALCULATIONS
FOR THREE PHASE HT LINES FOR DIFFERENT POLE OPTIONS
GROUND CLEARANCE : 15 FT. WIND PRESSURE = 8.00 LBS /SQ.FT.

NO.	DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)					PRESTRESSED CONCRETE (FT)						
			35' 1	30' 2	WAPDA 34.66' 3	WAPDA 31.17' 4	PTAT 31.17' 5	WAPDA 36' 6	WAPDA 31.17 7	PTAT 31.17' 8	LCP 29.5'(1) 9	LCP 29.5(2) 10	LCP 26.2 11	LCP 26.2' 12	LCP 27.6' 13	LCP 27.6' 14
1.	Mole	2	656	525	656	590	590	656	590	590	525		361		328	-
		2.5	656	525	656	590	590	656	590	590	525		361		328	
2.	Squirrel	2	689	558	689	558	558	754	558	558	492		394		328	
		2.5	689	536	639	558	558	754	558	558	492		394		328	-
3.	Gopher	2	722	558	722	623	623	722	623	623	551		394		295	-
		2.5	722	558	722	532	623	722	623	623	441		394		295	-
4.	Weasel	2	689	525	689	590	590	689	590	590	503	525	394	394	295	-
		2.5	576	436	689	485	590	689	590	590	402	525	394	394	295	
5.	Rabbit	2	656	492	656	469	574	656	575	575	389	492	328	328	295	
		2.5	577	492	656	375	574	656	460	460	311	492	328	328	295	
6.	Dog	2	512	299	656	333	525	656	408	408	276	404	289	394	295	332
		2.5	410	239	570	266	525	656	327	327	221	323	231	334	236	266
7.	Pelican	2	350	205	487	228	489	612	279	279	189	276	198	285	202	293
		2.5	280	164	390	182	391	490	223	223	151	221	158	228	161	234
8.	Panther	2	345	202	480	224	481	603	275	275	186	272	195	281	199	289
		2.5	276	161	384	179	385	482	220	220	148	217	156	225	159	231
9.	Osprey	2	326	190	455	212	454	569	260	260	175	257	184	266	184	223
		2.5	261	152	363	169	363	455	208	208	140	205	147	212	150	218

FS = Factor of Safety

TABLE T1 3
ALLOWABLE SPANS WITH REFERENCE TO SAG TENSION CALCULATIONS FOR
SINGLE PHASE HT LINES FOR DIFFERENT POLE OPTIONS
GROUND CLEARANCE : 15 FT. WIND PRESSURE 8 LBS./SQ.FT

NO.	DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)			PRESTRESSED CONCRETE (FT)								
		POLE	35' >1	30' 2	WAPDA 34.66' 3	WAPDA 31.17' 4	PTAT 31.17' 5	WAPDA 36' 6	WAPDA 31.17' 7	PTAT 31.17' 8	LCP 29.5'(1) 9	LCP 29.5'(2) 10	LCP 26.2' 11	LCP 26.2' 12	LCP 27.6' 13	LCP 27.6' 14
1	Mole	2	656	525	656	590	590	556	590	590	525		361		328	
		2.5	656	525	656	590	590	556	590	590	525	-	361		328	
2.	Squirrel	2	689	558	689	558	558	754	558	558	492	-	394		328	
		2.5	689	558	689	558	558	754	558	558	492	-	394		328	
3.	Gopher	2	722	558	722	623	623	722	623	623	558		394		295	
		2.5	722	558	722	623	623	722	623	623	558	-	394		295	
4.	Weasel	2	689	525	689	590	590	689	590	590	525	525	394	394	295	
		2.5	689	525	689	590	590	689	590	590	525	525	394	394	295	
5.	Rabbit	2	656	492	656	574	574	656	574	574	492	492	328	328	295	
		2.5	656	492	656	574	574	656	574	574	492	492	328	328	295	
6.	Dog	2	656	525	656	525	525	656	525	525	492	492	394	394	295	332
		2.5	656	525	656	525	525	656	525	525	492	492	394	394	295	332
7.	Pelican	2	590	459	590	525	525	656	525	525	459	459	328	328	262	262
		2.5	590	459	590	525	525	656	525	525	459	459	328	328	262	262
8.	Panther	2	772	525	722	590	590	722	590	590	525	525	394	394	328	328
		2.5	772	525	722	590	590	722	590	590	525	525	394	394	328	328
9.	Osprey	2	590	459	590	525	525	656	525	525	459	459	328	328	262	262
		2.5	590	459	590	525	525	656	525	525	459	459	328	328	262	262

FS - Factor of Safety

TABLE T1-4

RECOMMENDED SPANS WITH REFERENCE TO POLE STRENGTH AND SAG TENSION CALCULATIONS FOR SINGLE PHASE HT LINES FOR DIFFERENT POLE OPTIONS

GROUND CLEARANCE : 15 FT. WIND PRESSURE 8 LBS./SQ FT.

NO.	DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)					PRESTRESSED CONCRETE (FT)						
		POLE	35' 1	30' 2	WAPDA 34.66' 3	WAPDA 31.17' 4	PTAT 31.17' 5	WAPDA 36' 6	WAPDA 31.17' 7	PTAT 31.17' 8	LCP 29.5'(1) 9	LCP 29.5(2) 10	LCP 26.2' 11	LCP 26.2' 12	LCP 27.6' 13	LCP 27.6' 14
1.	Mole	2	656	525	656	590	590	556	590	590	525		361		328	
		2.5	556	525	656	590	590	556	590	590	525		361		328	
2.	Squirrel	2	689	558	689	558	558	754	558	558	492	-	394		328	
		2.5	689	558	689	558	558	754	558	558	492	-	394		328	
3.	Gopher	2	722	558	722	623	623	722	623	623	558	-	394		295	
		2.5	722	558	722	623	623	722	623	623	558	-	394		295	
4.	Weasel	2	689	525	689	590	590	689	590	590	525	525	394	394	295	
		2.5	689	525	689	590	590	689	590	590	525	525	394	394	295	
5.	Rabbit	2	656	492	656	574	574	656	574	574	492	492	328	328	295	
		2.5	656	492	656	563	574	656	574	574	492	492	328	328	295	
6.	Dog	2	656	525	656	525	525	656	525	525	492	492	394	394	295	332
		2.5	515	525	656	400	525	656	490	525	492	484	394	394	295	332
7.	Pelican	2	528	459	590	342	525	656	420	525	459	415	328	328	262	262
		2.5	422	410	585	274	525	656	336	525	459	332	328	328	242	262
8.	Panther	2	519	505	722	338	590	722	444	590	525	409	394	394	299	328
		2.5	415	404	577	270	578	722	331	590	525	327	377	338	239	328
9.	Osprey	2	490	459	590	319	525	656	390	525	459	386	328	328	262	262
		2.5	392	382	545	255	525	656	312	525	459	309	328	319	226	262

FS = Factor of Safety

TABLE T1 5
ALLOWABLE SPANS WITH REFERENCE TO SAG-TENSION CALCULATIONS
FOR THREE PHASE LT LINES FOR DIFFERENT POLE OPTIONS
GROUND CLEARANCE 15 FT. WIND PRESSURE = 8 LBS/SQ.FT.

NO. DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)					PRESTRESSED CONCRETE (FT)						
		35'	30'	WAPDA 34.66'	WAPDA 31.17'	PTAT 31.17'	WAPDA 36'	WAPDA 31.17'	PTAT 31.17'	LCP 29.5'(1)	LCP 29.5(2)	LCP 26.2'	LCP 25.2'	LCP 27.6'	LCP 27.6'
	POLE-->1		2	3	4	5	6	7	8	9	10	11	12	13	14
1. Goat															
a. Vertical	2	426	295	426	328	328	459	328	328	295	295	140	140	60	60
	2.5	426	295	426	328	328	459	328	328	295	295	140	140	60	60
b. Horizon-tal	2	525	426	525	459	459	525	459	459	426	426	328	328	262	262
	2.5	525	426	525	459	459	525	459	459	426	426	328	328	262	262
2. Ant															
a. Vertical	2	459	295	459	328	328	459	328	328	295	295	132	132	52	52
	2.5	459	295	459	328	328	459	328	328	295	295	132	132	52	52
b. Horizon tal	2	525	426	525	459	459	590	459	459	426	426	295	295	246	246
	2.5	525	426	525	459	459	590	459	459	426	426	295	295	246	246
3. Wasp															
a. Vertical	2	459	262	426	328	328	459	328	328	262	262	132	132	52	52
	2.5	459	262	426	328	328	459	328	328	262	262	132	132	52	52
b. Horizon tal	2	558	426	558	459	459	426	590	459	426	426	262	262	230	230
	2.5	558	426	558	459	459	426	590	459	426	426	262	262	230	230
4. Chafer															
a. Vertical	2	459	262	426	328	328	459	328	328	262	262	130	130	50	50
	2.5	459	262	426	328	328	459	328	328	262	262	130	130	50	50
b. Horizon tal	2	590	426	525	459	459	656	459	459	426	426	262	262	230	230
	2.5	590	426	525	459	459	656	459	459	426	426	262	262	230	230

TABLE T1-6

RECOMMENDED SPANS WITH REFERENCE TO SAG-TENSION CALCULATIONS AND POLE STRENGTH
FOR THREE PHASE LT LINES FOR DIFFERENT POLE OPTIONS
GROUND CLEARANCE : 15 FT. WIND PRESSURE = 8 LBS/SQ. FT.

NO. DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)					PRESTRESSED CONCRETE (FT)						
		35'	30'	WAPDA 34.66'	WAPDA 31.17'	PTAT 31.17'	WAPDA 36'	WAPDA 31.17'	PTAT 31.17'	LCP 29.5'(1)	LCP 29.5(2)	LCP 26.2'	LCP 26.2'	LCP 27.6'	LCP 27.6'
	POLE-->1		2	3	4	5	6	7	8	9	10	11	12	13	14
1. Goat															
a. Vertical	2	426	295	426	328	328	459	328	328	295	295	140	140	60	60
	2.5	426	295	426	328	328	459	328	328	295	295	140	140	60	60
b. Horizontal	2	525	383	525	427	459	525	459	459	353	426	328	328	262	262
	2.5	525	307	525	341	459	525	418	418	283	415	296	328	262	262
2. Ant															
a. Vertical	2	459	295	459	328	328	459	328	328	295	295	132	132	52	52
	2.5	459	295	459	328	328	459	328	328	295	295	132	132	52	52
b. Horizontal	2	525	399	525	444	459	590	459	459	368	426	295	295	246	426
	2.5	525	319	525	335	459	590	435	435	294	426	295	295	246	246
3. Wasp															
a. Vertical	2	459	262	426	314	328	459	328	328	262	262	132	132	52	52
	2.5	375	228	426	251	328	459	308	308	212	262	132	132	52	52
b. Horizontal	2	381	223	530	248	459	426	304	304	205	300	215	262	220	230
	2.5	305	178	424	198	425	426	243	243	164	240	172	248	176	230
4. Chafer															
a. Vertical	2	347	211	426	232	328	459	285	285	196	262	130	130	50	50
	2.5	277	169	387	186	328	459	228	228	156	229	130	130	50	50
b. Horizontal	2	282	165	392	183	393	493	225	225	152	222	159	230	162	230
	2.5	226	132	314	147	315	394	180	180	121	178	127	184	130	189

FS = Factor of Safety

TABLE T1-7

ALLOWABLE SPANS WITH REFERENCE TO SAG-TENSION CALCULATIONS FOR THREE PHASE COMPOSITE LINES FOR DIFFERENT POLE OPTIONS

GROUND CLEARANCE : 15 FT. WIND PRESSURE = 8 Lbs/sq. ft.

NO. DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)					PRESTRESSED CONCRETE (FT)						
		35'	30'	WAPDA 34.66'	WAPDA 31.17'	PTAT 31.17'	WAPDA 36'	WAPDA 31.17'	PTAT 31.17'	LCP 29.5'(1)	LCP 29.5(2)	LCP 26.2'	LCP 26.2'	LCP 27.6'	LCP 27.6'
	POLE->1		2	3	4	5	6	7	8	9	10	11	12	13	14
1. Goat + Squirel															
a. Vertical	2	328	148	328	164	164	328	164	164	131	131	-		-	-
	2.5	328	148	328	164	164	328	164	164	131	131	-	-		-
b. Horizontal	2	394	328	426	328	328	426	328	328	295	295	164	164	66	66
	2.5	394	328	426	328	328	426	328	328	295	295	164	164	66	66
2. Ant + Gopher															
a. Vertical	2	328	131	328	164	164	328	164	164	98	98	-	-	-	
	2.5	328	131	328	164	164	328	164	164	98	98	-	-	-	-
b. Horizontal	2	459	328	459	328	328	459	328	328	295	295	148	148	66	66
	2.5	459	328	459	328	328	459	328	328	295	295	148	148	66	66
3. Wasp + Rabbit															
a. Vertical	2	328	131	328	164	164	328	164	164	98	98	-		-	-
	2.5	328	131	328	164	164	328	164	164	98	98	-	-	-	-
b. Horizontal	2	459	262	459	328	328	492	328	328	262	262	148	148	66	66
	2.5	459	262	459	328	328	492	328	328	262	262	148	148	66	66
4. Chafer + Dog															
a. Vertcial	2	328	131	328	159	164	328	164	164	96	98	-	-	-	-
	2.5	328	131	328	159	164	328	164	164	96	98	-	-	-	-
b. Horizontal	2	459	262	459	328	328	459	328	328	262	262	148	148	66	66
	2.5	459	262	459	328	328	459	328	328	262	262	148	148	66	66

FS = Factor of Safety

TABLE T1-8
RECOMMENDED SPANS WITH REFERENCE TO SAG-TENSION CALCULATIONS AND
POLE STRENGTH FOR THREE PHASE COMPOSITE LINE
GROUND CLEARENCE : 15 ft. WIND PRESSURE = 8 lbs./sq. ft.

NO. DESCRIPTION	FS	WOOD POLE (FT)		STEEL LATTICE (FT)			PRESTRESSED CONCRETE (FT)								
		35'	30'	WAPDA 34.66'	WAPDA 31.17'	PTAT 31.17'	WAPDA 36'	WAPDA 31.17'	PTAT 31.17'	LCP 29.5'(1)	LCP 29.5(2)	LCP 26.2'	LCP 26.2'	LCP 27.6'	LCP 27.6'
	POLE-->1		2	3	4	5	6	7	8	9	10	11	12	13	14
1. Goat + Squirel															
a. Vertical	2	328	148	328	164	164	328	164	164	131	131				
	2.5	328	148	328	164	164	328	164	164	131	131				
b. Horizon-	2	394	244	426	271	328	426	328	328	225	295	164	164	66	66
tal	2.5	334	195	426	217	328	426	266	266	180	262	164	164	66	66
2. Ant + Gopher															
a. Vertical	2	328	131	328	164	164	328	164	164	98	98	-	-		-
	2.5	318	131	328	164	164	328	164	164	98	98	-	-	-	-
b. Horizon-	2	409	239	159	266	328	459	326	326	220	295	148	148	66	66
tal	2.5	327	191	455	213	328	459	261	261	176	258	148	148	66	66
3. Wasp + Rabbit															
a. Vertical	2	284	131	328	164	164	328	164	164	98	98	-			
	2.5	227	131	316	150	164	328	164	164	98	98	-			
b. Horizon	2	249	146	347	162	328	436	191	191	134	196	140	148	66	66
tal	2.5	199	116	277	129	278	348	159	159	107	157	112	148	66	66
4. Chafer + Dog															
a. Vertcial	2	207	124	288	137	164	328	164	164	96	98				
	2.5	165	993	230	109	164	288	134	134	91	98				
b. Horizon	2	182	106	253	118	253	318	145	145	98	143	102	148	66	66
tal	2.5	145	850	202	94	203	254	116	116	78	114	82	118	66	66

FS = Factor of Safety

TABLE TI-9
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 10 2 lbs/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Mole	656	525	656	590	590	656	590	590	525	-	361	-	323	
2	Squirrel, Gopher and Weasel	576	336	639	368	590	689	444	444	308	453	325	394	295	-
3	Rabbit	446	260	614	285	574	656	343	343	238	350	251	329	236	
4	Dog	317	184	437	202	439	544	244	244	169	249	179	259	192	266
5	Panther, Pelican	216	126	298	138	300	372	166	166	115	170	122	176	124	182
6	Osprey	201	117	277	128	279	346	155	155	107	158	113	164	116	169
	NUMBER OF STRUCTURES PER KM														
1	Mole	5 00	6 25	5 00	5 56	5 56	5 00	5 56	5 56	6 25	0 00	9 09	0 00	10 00	0 00
2	Squirrel, Gopher and Weasel	5 69	9 76	4 76	8 91	5 56	4 76	7 39	7 39	10 65	7 24	10 09	6 32	11 12	0 00
3	Rabbit	7 35	12 62	5 34	11 51	5 71	5 00	9 56	9 56	13 78	9 37	13 07	10 00	11 12	0 00
4	Dog	10 35	17 83	7 51	16 24	7 47	6 03	13 44	13 44	19 41	13 17	18 43	12 71	18 02	12 33
5	Panther, Pelican	15 19	26 03	11 01	23 77	10 93	8 82	19 76	19 76	28 52	19 29	26 89	18 64	26 45	18 02
6	Osprey	16 32	28 03	11 84	25 63	11 76	9 48	21 16	21 16	30 65	20 76	29 03	20 00	28 28	19 41
	UNIT COSTS OF CONSTRUCTION (Rs)														
1	Structure	3760	2268	3717	2646	2946	2646	1512	1506	945	1005	659	818	575	756
2	Hardware & Foundation	650	650	1790	1790	1790	650	650	650	650	650	650	650	650	650
	COST OF CONSTRUCTION (Rs)														
1	Mole														
a	Structures	16900	14175	18555	14712	16380	13230	8407	8373	5263	0	5990	0	5750	0
b	Hardware & Foundation	3250	4063	8950	9952	9952	3250	3614	3614	4063	0	5909	0	6500	0
c	Total	22150	18238	27535	24664	26332	16480	12021	11987	9331	0	11899	0	12250	0
2	Squirrel, Gopher and Weasel														
a	Structures	21508	22136	17693	23576	16380	12595	11174	11129	8978	7276	6843	6806	6394	0
b	Hardware & Foundation	3699	6344	8520	15949	9952	3094	4804	4604	6323	4706	6559	5408	7228	0
c	Total	25207	28480	26213	39525	26332	15689	15977	15733	15300	11982	13208	12214	13622	0

TABLE T1-9

COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE HT LINES PER KM

BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5

WIND PRESSURE = 10.2 lbs/sq ft.

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Rabbit														
	a Structures	27783	28622	19849	30455	16822	13230	14455	14397	11617	9417	8613	8180	6394	0
	b Hardware & Foundation	4778	8203	9559	20603	10221	3250	6214	6214	8957	6091	8496	6500	7228	0
	c Total	32561	36825	29407	51058	27043	16480	20669	20611	20574	15507	17109	14680	13622	0
4	Dog														
	a Structures	39123	40438	27915	42971	22007	15955	20321	20241	16363	13236	12145	10397	10352	8952
	b Hardware & Foundation	6728	11590	13443	29070	13371	3920	8736	8736	12617	8561	11980	8262	11713	8015
	c Total	45851	52028	41358	72041	35378	19875	29057	28977	28979	21796	24125	18658	22075	16966
5	Panther, Felican														
	a Structures	57418	59036	40924	62895	32200	23338	29877	29759	24042	19386	17721	15248	15209	13083
	b Hardware & Foundation	9874	16920	19708	42548	19565	5733	12844	12844	18538	12539	17479	12116	17193	11713
	c Total	67292	75956	60632	105444	51764	29071	4272[illegible]	42603	42580	31925	35199	27364	32401	24796
6	Osprey														
	a Structures	61690	63572	44003	67817	34645	25084	31994	31867	25833	20864	19131	16360	16261	14032
	b Hardware & Foundation	10608	18220	21194	45878	21050	6162	13754	13754	19923	13494	18870	13000	18382	12617
	c Total	72298	81792	65203	113695	55695	31246	45748	45621	45760	34358	38000	29360	34643	26705

TABLE T1-10
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 10.2 lbs/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Mole	656	525	656	590	590	656	590	590	525	-	361	-	328	
2	Squirrel	659	553	689	559	559	754	559	559	432		394		328	
3	Gopher	722	559	722	623	623	722	623	623	559		394		255	
4	Weasel	689	525	689	590	590	689	590	590	525	525	394	394	295	
5	Rabbit	656	492	656	442	574	656	574	574	492	492	328	328	295	
6	Dog	492	525	656	314	525	656	394	525	492	394	394	394	295	262
7	Pelican	331	322	459	215	525	656	264	525	459	[illegible]	328	328	190	262
8	Panther	325	317	453	212	453	722	264	590	525	256	256	265	197	323
9	Osprey	307	300	427	200	525	656	245	[illegible]	459	242	323	250	177	262
	NUMBER OF STRUCTURES PER KM														
1	Mole	5.00	6.25	5.00	5.56	5.56	5.00	5.56	5.56	6.25	0.00	8.09	0.00	10.00	0.00
2	Squirrel	4.76	5.88	4.76	5.88	5.88	4.35	5.88	5.88	6.67	0.00	8.32	0.00	10.00	0.00
3	Gopher	4.54	5.88	4.54	5.26	5.26	4.54	5.26	5.26	5.88	0.00	8.32	0.00	11.12	0.00
4	Weasel	4.76	6.25	4.76	5.56	5.56	4.76	5.56	5.56	6.25	6.25	8.32	8.32	11.12	0.00
5	Rabbit	5.00	6.67	5.00	7.42	5.71	5.00	5.71	5.71	6.67	6.67	10.00	10.00	11.12	0.00
6	Dog	6.80	6.25	5.00	10.45	6.25	5.00	8.54	6.25	6.67	8.66	8.32	8.32	11.12	9.38
7	Pelican	9.91	10.19	7.15	15.26	6.25	5.00	12.42	6.25	7.15	12.62	10.00	10.00	17.26	12.52
8	Panther	10.09	10.35	7.24	15.47	7.24	4.54	12.62	5.56	6.25	12.31	11.08	12.38	17.54	10.00
9	Osprey	10.68	10.93	7.68	16.40	6.25	5.00	13.39	6.25	7.15	13.55	10.00	13.12	18.53	12.52
	UNIT COSTS OF CONSTRUCTION (Rs.)														
1	Structure	3780	2268	3717	2646	2946	2646	1512	1566	543	1008	653	315	575	226
2	Hardware & Foundation	565	565	1705	1705	1705	565	565	565	565	565	565	565	565	565
	COST OF CONSTRUCTION (Rs.)														
1	Mole														
a	Structures	15900	14175	18585	14712	16380	13230	3407	3372	5269	0	5550	0	5750	-
b	Hardware & Foundation	2825	3531	8525	9480	9480	2825	3141	3141	3531	0	5126	0	5650	-
c	Total	21725	17706	27110	24192	25860	16055	11548	11515	8800	-	11126	0	11400	-

TABLE T1-10
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 10 2 lbs/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
2	Squirrel														
a	Structures	17593	13336	17693	15553	17322	11510	8391	8355	5623	0	5483	0	5750	0
b	Hardware & Foundation	2689	3322	8116	10025	10025	2458	3322	3322	3763	0	4701	0	5650	0
c	Total	20682	16658	25809	25584	27348	13968	12213	12177	9391	0	10184	0	11400	0
3	Gopher														
a	Structures	17161	13336	16875	13918	15496	12013	7953	7322	4957	0	5483	0	6394	0
b	Hardware & Foundation	2565	3322	7741	8968	8968	2565	2972	2972	3322	0	4701	0	6283	0
c	Total	19726	16658	24616	22886	24464	14578	10925	10693	8279	0	10184	0	12677	0
4	Weasel														
a	Structures	17593	14175	17693	14712	16380	12595	8407	8373	5269	6281	5483	6806	6394	0
b	Hardware & Foundation	2689	3531	8116	9480	9480	2689	3141	3141	3531	3531	4701	4701	6283	0
c	Total	20682	17706	25809	24192	25860	15284	11548	11515	8800	9813	10184	11507	12677	0
5	Rabbit														
a	Structures	18900	15128	18585	19633	16822	13230	8634	8599	5623	6703	6530	8130	6394	0
b	Hardware & Foundation	2825	3769	8525	12651	9736	2825	3226	3226	3763	3769	5650	5650	6283	0
c	Total	21725	18896	27110	32284	26557	16055	11860	11825	9391	10472	12240	13830	12677	0
6	Dog														
a	Structures	25704	14175	18585	27651	18413	13230	12912	9413	5623	8673	5483	6806	6394	7173
b	Hardware & Foundation	3842	3531	8525	17817	10656	2825	4825	3531	3769	4876	4701	4701	6283	5582
c	Total	29546	17706	27110	45468	29069	16055	17738	12944	9391	13549	10184	11507	12677	12755
7	Panther														
a	Structures	37460	23111	26577	40378	18413	13230	18779	9413	6027	12683	6550	8130	9025	9590
b	Hardware & Foundation	5599	5757	12191	[illegible]	10656	2825	7017	3531	4040	7130	5650	5650	8752	7574
c	Total	43059	28868	38767	66396	29069	16055	25796	12944	10067	19813	12240	13830	14576	16163

TABLE T1-10
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 10.2 lbs/sq.ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
8	Pelican														
	a Structures	35140	23474	26311	40934	21329	12013	19081	8373	5269	12874	7302	10127	10086	7260
	b Hardware & Foundation	5701	5848	12944	26376	12344	2565	7130	3141	3531	7238	6260	6995	9310	5650
	c Total	40841	29322	39255	67310	33673	14578	26212	11515	8800	20112	13562	17122	19396	12910
9	Osprey														
	a Structures	40370	24789	28547	43394	18413	13230	20246	9413	6027	13618	6590	10732	10655	9090
	b Hardware & Foundation	6035	6175	13094	27962	10656	2825	7565	3531	4040	7656	5650	7413	10469	7074
	c Total	46405	30965	41641	71356	29069	16055	27811	12944	10067	21274	12240	18145	21124	16163

TABLE T1-11
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 8 lb/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Mole	656	525	656	550	590	656	590	590	525	-	361	-	323	-
2	Squirrel, Gopher and Weasel	576	436	689	485	590	689	590	590	402	525	334	394	295	-
3	Rabbit	577	492	656	375	574	656	460	460	311	492	326	323	295	-
4	Dog	410	239	570	266	525	656	327	327	221	323	231	234	226	166
5	Panther, Pelican	280	164	350	192	391	490	223	223	151	221	153	229	161	274
6	Osprey	261	152	363	163	363	455	208	208	140	205	147	212	150	213
	NUMBER OF STRUCTURES PER KM														
1	Mole	5 00	6 25	5 00	5 56	5 56	5 00	5 56	5 56	6 25	0 00	9 09	0 00	10 00	0 00
2	Squirrel, Gopher and Weasel	5 69	7 52	4 76	6 76	5 56	4 76	5 56	5 56	8 16	6 25	8 32	8 32	11 12	0 00
3	Rabbit	5 68	6 67	5 00	8 75	5 71	5 00	7 13	7 13	10 55	6 67	10 00	10 00	11 12	0 00
4	Dog	8 00	13 72	5 75	12 33	6 25	5 00	10 03	10 03	14 84	10 15	14 20	3 92	13 90	0 00
5	Panther, Pelican	11 71	20 00	8 41	18 02	8 39	6 69	14 71	14 71	21 72	14 84	20 76	14 39	20 37	14 02
6	Osprey	12 57	21 58	9 04	19 41	9 04	7 21	15 77	15 77	23 43	16 00	22 31	15 47	21 87	15 05
	UNIT COSTS OF CONSTRUCTION (Rs)														
1	Structure	3750	2268	3717	2646	2946	2646	1512	1506	843	1005	659	818	575	726
2	Hardware & Foundation	650	650	1790	1790	1790	650	650	650	650	650	650	650	650	650
	COST OF CONSTRUCTION (Rs)														
1	Mole														
a	Structures	18900	14175	18585	14712	16380	13230	8407	8373	5263	0	5990	0	5750	0
b	Hardware & Foundation	3250	4063	8950	9952	9952	3250	3614	3614	4063	0	5909	0	6500	0
c	Total	22150	18238	27535	24664	26332	16480	12021	11987	9331	0	11899	0	12250	0
2	Squirrel, Gopher and Weasel														
a	Structures	21568	17055	17693	17887	16380	12595	8407	5073	6879	6231	5483	6806	6334	0
b	Hardware & Foundation	3639	4888	8520	12100	9952	3094	3614	3614	5304	4063	5408	5408	7228	0
c	Total	25207	21943	26213	29987	26332	15689	12021	11987	12183	10344	10891	12214	13622	

TABLE T1-11
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lb/sq.ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Rabbit														
a	Structures	21470	15128	18585	23153	16822	13230	10781	10738	8894	6703	6529	5180	6394	0
b	Hardware & Foundation	3692	4336	8950	15663	10221	3250	4635	4635	6858	4336	6500	6500	7228	0
c	Total	25162	19463	27535	38815	27043	16480	15415	15372	15751	11039	13090	14680	13622	0
4	Dog														
a	Structures	30240	31117	21373	32625	18413	13230	15165	15105	12510	10201	9358	8033	7993	0
b	Hardware & Foundation	5200	8918	10293	22071	11188	3250	6520	6520	9646	6598	9230	6383	9035	0
c	Total	35440	40035	31665	54696	29600	16480	21685	21625	22156	16798	18588	14416	17028	0
5	Fantner, Pelican														
a	Structures	44264	45360	31260	47681	24717	17702	22242	22153	18310	14914	13681	11771	11713	10179
b	Hardware & Foundation	7612	13000	15054	32256	15018	4349	9562	9562	14118	9646	13494	9354	13241	9113
c	Total	51875	58360	46314	79937	39735	22050	31803	31715	32428	24560	27175	21125	24953	19292
6	Osprey														
a	Structures	47515	48943	33602	51359	26632	19078	23844	23750	19751	16080	14702	12654	12575	10926
b	Hardware & Foundation	8171	14027	16182	34744	16182	4687	10251	10251	15230	10400	14502	10056	14216	9783
c	Total	55685	62970	49783	86103	42813	23764	34095	34000	34981	26480	29204	22710	26791	20709

TABLE TI-12
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lb/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Mole	656	525	656	590	590	656	590	590	525	-	361	-	323	
2	Squirrel	659	558	659	558	558	754	558	558	432	-	394	-	323	-
3	Gopher	722	558	722	623	623	722	623	623	558	-	394	-	256	-
4	Weasel	659	525	659	590	590	659	590	590	525	525	394	394	255	-
5	Rabbit	656	492	656	563	574	656	574	574	492	492	328	328	255	-
6	Dog	615	525	656	400	525	656	490	525	492	484	394	394	255	332
7	Pelican	422	410	595	274	525	656	336	525	459	332	328	328	242	362
8	Panther	415	404	577	270	578	722	331	590	525	327	377	348	259	328
9	Osprey	392	392	545	255	525	656	312	525	459	309	328	319	226	362
	NUMBER OF STRUCTURES PER KM														
1	Mole	5.00	6.25	5.00	5.56	5.56	5.00	5.56	5.56	6.25	0.00	9.00	0.00	10.00	0.00
2	Squirrel	4.76	5.88	4.76	5.88	5.88	4.35	5.88	5.88	6.67	0.00	8.32	0.00	10.00	0.00
3	Gopher	4.54	5.88	4.54	5.26	5.26	4.54	5.26	5.26	5.88	0.00	8.22	0.00	11.12	0.00
4	Weasel	4.76	6.25	4.76	5.56	5.56	4.76	5.56	5.56	6.25	6.25	8.32	8.32	11.12	0.00
5	Rabbit	5.00	6.67	5.00	5.83	5.71	5.00	5.71	5.71	6.67	6.67	10.00	10.00	11.12	0.00
6	Dog	5.33	6.25	5.00	8.20	6.25	5.00	6.69	6.25	6.67	6.78	8.32	8.32	11.12	9.38
7	Pelican	7.77	9.00	5.61	11.97	6.25	5.00	9.76	6.25	7.15	9.88	10.00	10.00	13.55	12.52
8	Panther	7.90	8.12	5.68	12.15	5.67	4.54	9.91	5.56	6.25	10.03	8.70	9.70	13.72	10.00
9	Osprey	8.37	8.59	6.02	12.86	6.25	5.00	10.51	6.25	7.15	10.61	10.00	10.23	14.51	12.52
	UNIT COSTS OF CONSTRUCTION (Rs.)														
1	Structure	3720	2268	3717	2646	2946	2646	1512	1506	843	1005	659	818	575	726
2	Hardware & Foundation	565	565	1705	1705	1705	565	565	565	565	565	565	565	565	565
	COST OF CONSTRUCTION (Rs.)														
1	Pole														
a	Structures	18600	14175	18585	14712	16380	13230	8407	8373	5269	0	5930	0	5750	0
b	Hardware & Foundation	2825	3531	8525	9480	9480	2925	3141	3141	3531	0	5126	0	[illegible]	0
c	Total	21425	17706	27110	24192	25860	16055	11548	11515	[illegible]	0	11125	[illegible]	[illegible]	

TABLE TI-12
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lb/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
2	Squirrel														
	a Structures	17993	13336	17693	15558	17322	11510	8891	8855	5623	0	5483	0	5750	0
	b Hardware & Foundation	2689	3322	8116	10025	10025	2458	3322	3322	3763	0	4701	0	5650	0
	c Total	20682	16658	25809	25584	27348	13968	12213	12177	9391	0	10184	0	11400	0
3	Gopher														
	a Structures	17161	13336	16875	13918	15496	12013	7953	7922	4957	0	5483	0	6394	0
	b Hardware & Foundation	2565	3322	7741	8968	8968	2565	2972	2972	3322	0	4701	0	6283	0
	c Total	19726	16658	24616	22886	24464	14578	10925	10893	8273	0	10184	0	12677	0
4	Weasel														
	a Structures	17993	14175	17693	14712	16380	12595	8407	8373	5269	6281	5483	6806	6394	0
	b Hardware & Foundation	2689	3531	8116	9480	9480	2689	3141	3141	3531	3531	4701	4701	6283	0
	c Total	20682	17706	25809	24192	25860	15284	11548	11515	8800	9813	10184	11507	12677	0
5	Rabbit														
	a Structures	18900	15128	18585	15426	16822	13230	8634	8599	5623	6703	6550	8130	6394	0
	b Hardware & Foundation	2825	3769	8525	9940	9736	2825	3226	3226	3763	3769	5650	5650	6283	0
	c Total	21725	18896	27110	25366	26557	16055	11860	11825	9391	10472	12240	13830	12677	0
6	Dog														
	a Structures	20147	14175	18585	21697	18413	13220	10115	9413	5623	6314	5483	6806	6394	7173
	b Hardware & Foundation	3011	3531	8525	13981	10656	2825	3780	3531	3763	3531	4701	4701	6283	5512
	c Total	23159	17706	27110	35678	29069	16055	13895	12944	9391	10645	10184	11507	12677	12755
7	Panther														
	a Structures	29371	19144	20852	31673	18413	13230	14757	9413	6027	9329	6550	8130	7791	8790
	b Hardware & Foundation	4390	4520	9565	20406	10656	2825	5514	3531	4040	5532	5650	5650	7656	7074
	c Total	33761	22664	30417	52081	29069	16055	20272	12944	10067	15512	12240	13830	15447	16163

TABLE T1-12
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE HT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lb/sq ft

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
8	Pelican														
	a Structures	29862	18416	21113	32149	16704	12013	14934	8373	5269	10380	5733	7935	7889	7260
	b Hardware & Foundation	4464	4588	9684	20716	9667	2565	5599	3141	3531	5667	4316	5481	7752	5650
	c Total	34326	23004	30797	52865	26371	14578	20583	11515	8800	15747	10649	13415	15641	12910
9	Osprey														
	a Structures	31639	19482	22376	34028	18413	13230	16891	9413	6027	10663	6530	8409	8343	9060
	b Hardware & Foundation	4729	4853	10264	21926	10656	2825	5938	3531	4040	5935	5550	5808	8193	7074
	c Total	36368	24335	32640	55954	29069	16055	21829	12944	10067	16658	12240	14217	16541	16163

TABLE T1-13
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lb/sq ft
HORIZONTAL FORMATION

S. No.	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Gnat	525	307	525	341	459	525	419	418	293	413	296	326	262	262
2	Ant	525	349	525	335	459	550	435	435	234	426	255	255	246	246
3	Wasp	305	178	424	198	425	426	243	243	164	240	172	243	176	229
4	Chafer	226	132	314	147	315	394	180	180	121	178	127	184	130	169
	NUMBER OF STRUCTURES PER KM														
1	Gnat	6.25	10.68	6.25	9.62	7.15	6.25	7.85	7.85	11.59	7.94	11.08	10.00	12.52	12.52
2	Ant	6.25	10.28	6.25	9.79	7.15	5.56	7.54	7.54	11.16	7.70	11.12	11.12	13.33	13.33
3	Wasp	10.75	18.43	7.74	16.57	7.72	7.70	13.50	13.50	20.00	13.67	19.07	13.23	18.64	14.26
4	Chafer	14.51	24.85	10.45	22.31	10.41	8.32	18.22	18.22	27.11	18.43	25.93	17.93	25.23	17.35
	UNIT COSTS OF CONSTRUCTION (Rs.)														
1	Structure	3780	2268	3717	2646	2946	2646	1512	1506	943	1005	653	613	575	726
2	Hardware & Foundation	339	339	1473	1378	1378	339	339	339	339	339	339	339	339	339
	COST OF CONSTRUCTION (Rs.)														
1	Gnat														
	a Structures	22625	24222	23231	25455	21064	16538	11869	11822	3770	7550	7302	5180	7133	9129
	b Hardware & Foundation	2119	3621	9206	13256	9853	2119	2661	2661	3929	2692	3756	3390	4244	4244
	c Total	25744	27843	32438	38711	30917	18656	14530	14483	13639	10671	11058	11570	11433	13324
2	Ant														
	a Structures	22625	22315	23231	25904	21064	14712	11400	11355	9408	7739	7329	5996	7665	9578
	b Hardware & Foundation	2119	3485	9206	13491	9853	1685	2556	2556	3783	2610	3770	3770	4513	4513
	c Total	25744	26800	32438	39395	30917	16597	13957	13911	13191	10349	11099	12966	12174	14156

TABLE T1-13
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 8 lb/sq ft
HORIZONTAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wasp														
	a Structures	40635	41799	28770	43844	22743	20374	20412	20331	16560	13738	12567	10522	10718	10353
	b Hardware & Foundation	3644	6248	11401	22833	10638	2610	4577	4577	6780	4634	6465	4485	6319	4834
	c Total	44279	48047	40171	66678	33381	22985	24989	24908	23640	18372	19032	15307	17037	15187
4	Chafer														
	a Structures	54848	56360	38843	59032	30668	22015	27549	27439	22854	18522	17022	14585	14507	12596
	b Hardware & Foundation	4919	8424	15393	30743	14345	2820	6177	6177	9190	6248	8756	6044	8553	5882
	c Total	59767	64784	54236	89775	45013	24835	33725	33616	32044	24770	25778	20629	23060	18478

TABLE TI-14
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 8 lbs/sq ft
VERTICAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Gnat	426	295	426	328	328	459	328	328	295	295	140	14	50	52
2	Ant	459	295	459	328	328	459	328	328	295	295	132	132	52	52
3	Wasp	375	228	426	251	328	459	308	308	212	262	132	132	52	52
4	Chafer	277	169	387	196	328	459	228	228	156	229	130	130	50	50
	NUMBER OF STRUCTURES PER KM														
1	Gnat	7 70	11 12	7 70	10 00	10 00	7 15	10 00	10 00	11 12	11 12	23 43	23 43	54 67	54 67
2	Ant	7 15	11 12	7 15	10 00	10 00	7 15	10 00	10 00	11 12	11 12	24 85	24 85	63 08	63 08
3	Wasp	8 75	14 39	7 70	13 07	10 00	7 15	10 65	10 65	15 47	12 52	24 85	24 85	63 08	63 08
4	Chafer	11 84	19 41	8 48	17 63	10 00	7 15	14 39	14 39	21 03	14 32	25 23	25 23	65 60	65 60
	UNIT COSTS OF CONSTRUCTION (Rs)														
1	Structure	3760	2268	3717	2646	2946	2646	1512	1506	943	1005	659	613	575	726
2	Hardware & Foundation	198	198	1331	1237	1237	198	198	198	198	198	198	198	198	198
	COST OF CONSTRUCTION (Rs)														
1	Gnat														
a	Structures	29106	25220	28621	26460	29460	18919	15120	15060	9374	11176	15440	13166	31435	39630
b	Hardware & Foundation	1525	2202	10249	12370	12370	1416	1980	1980	2202	2202	4639	4639	10825	10825
c	Total	30631	27422	38870	38830	41830	20335	17100	17040	11576	13377	20080	22805	42260	50515
2	Ant														
a	Structures	27027	25220	26577	26460	29460	18919	15120	15060	9374	11176	16376	20327	36271	45736
b	Hardware & Foundation	1416	2202	9517	12370	12370	1416	1980	1980	2202	2202	4520	4520	12430	12430
c	Total	28443	27422	36093	38830	41830	20335	17100	17040	11576	13377	21256	25243	48761	58256

TABLE T1-14
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR THREE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lbs/sq.ft.
VERTICAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wasp														
	a Structures	33075	32637	28621	34583	29460	18919	16103	16039	13041	12583	16376	20327	36271	45796
	b Hardware & Foundation	1733	2849	10249	16168	12370	1416	2109	2109	3063	2479	4920	4920	12490	12490
	c Total	34808	35486	38870	50751	41830	20335	18212	18148	16104	15062	21296	25248	48761	58286
4	Chafer														
	a Structures	44755	44022	31520	46649	29460	18919	21758	21671	17728	14392	16627	20638	37720	47626
	b Hardware & Foundation	2344	3843	11287	21808	12370	1416	2849	2849	4164	2835	4996	4996	12989	12989
	c Total	47100	47865	42807	68457	41830	20335	24607	24521	21892	17227	21622	25634	50709	60614

TABLE T1-15
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2.5
WIND PRESSURE = 8 lbs/sq ft
HORIZONTAL FORMATION

Sr. No.	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
	SPAN LENGTHS														
1	Gnat	525	426	525	459	459	525	459	459	426	426	323	323	262	262
2	Ant	525	403	525	449	459	590	459	459	372	426	295	295	246	246
3	Wasp	511	299	559	333	459	426	408	408	276	403	262	262	220	220
4	Chafer	392	229	545	255	546	656	312	312	211	309	221	262	226	220
	NUMBER OF STRUCTURES PER KM														
1	Gnat	6.25	7.70	6.25	7.15	7.15	6.25	7.15	7.15	7.70	7.70	10.00	10.00	12.52	12.52
2	Ant	6.25	8.14	6.25	7.31	7.15	5.56	7.15	7.15	8.82	7.70	11.12	11.12	13.33	13.33
3	Wasp	6.42	10.97	5.88	9.85	7.15	7.70	8.04	8.04	11.88	8.14	12.52	12.52	14.26	14.26
4	Chafer	8.37	14.32	6.02	12.86	6.01	5.00	10.51	10.51	15.55	10.61	14.84	12.52	14.51	14.26
	UNIT COSTS OF CONSTRUCTION (Rs.)														
1	Structure	3780	2268	3717	2646	2946	2646	1512	1506	843	1005	659	813	575	726
2	Hardware & Foundation	285	285	1324	1324	1324	285	285	285	285	285	285	285	285	285
	COST OF CONSTRUCTION (Rs.)														
1	Gnat														
	a Structures	22625	17464	23231	18919	21064	16538	10811	10768	6491	7753	6550	8130	7133	9090
	b Hardware & Foundation	1731	2195	8275	9467	9467	1781	2039	2039	2195	2195	2850	2850	3563	3563
	c Total	25406	19658	31506	28386	30531	18319	12849	12806	8686	9933	9440	11030	10767	12653
2	Ant														
	a Structures	22625	19462	22231	19342	21064	14712	10911	10768	7435	7733	7323	9096	7665	9673
	b Hardware & Foundation	1731	2320	8275	9678	9467	1585	2039	2039	2514	2195	3169	3169	3799	3799
	c Total	25406	20781	31506	29021	30531	16296	12849	12806	9949	9933	10497	12265	11464	13477

TABLE TI-15
COST COMPARISON OF DIFFERENT POLE OPTIONS FOR SINGLE PHASE LT LINES PER KM
BASED ON MAXIMUM ALLOWABLE SPAN LENGTHS AND FACTOR OF SAFETY 2 5
WIND PRESSURE = 8 lbs/sq ft
HORIZONTAL FORMATION

Sr No	DESCRIPTION	POLE 1	POLE 2	POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	Wasp														
a	Structures	24268	24880	21856	26063	21064	20374	12156	12108	10015	8181	8251	10241	8200	10353
b	Hardware & Foundation	1830	3126	7785	13041	9467	2195	2291	2291	3386	2320	3568	3568	4064	4064
c	Total	26097	28006	29641	39105	30531	22569	14448	14400	13401	10501	11819	13810	12264	14417
4	Chafer														
a	Structures	31639	32478	22376	34028	17705	13230	15891	15828	13109	10663	9780	10241	8343	10353
b	Hardware & Foundation	2385	4081	7970	17027	7957	1425	2995	2995	4432	3024	4229	3568	4135	4064
c	Total	34024	36559	30347	51054	25663	14655	18886	18823	17540	13687	14009	13810	12479	14417

ANNEX T2
DESIGN STUDIES OF CONDUCTOR SIZES

ANNEX T2

DESIGN STUDIES OF CONDUCTOR SIZES

1 SCOPE

As many as 24 case studies were carried out to find out as to what would be the most economical option of conductor application on a given three phase 11 kV line. A typical feeder F1, emanating from grid station GS8, Tehsil and District Okara, with three T-offs, was selected for this purpose. Voltage regulation was also considered where excessive voltage drop so demanded.

2 CONFIGURATIONS

The different alternative arrangements of conductor application and voltage regulation, which were studied, are summarised below:

CASE	MAIN LINE CONDUCTOR (SECTIONS)	BRANCH LINE CONDUCTOR (SECTIONS)	VOLTAGE REGULATOR
1.	G (6)	M (3)	NO
2.	G (6)	M (3)	YES
3.	R (6)	M (3)	NO
4.	R (6)	M (3)	YES
5.	D (6)	M (3)	YES
6.	D (6)	M (3)	NO
7.	D (1), R(5)	M (3)	NO
8.	D (2), R(4)	M (3)	NO
9.	D (3), R(3)	M (3)	NO
10.	D (4), R(2)	M (3)	No
11.	D (4), R(2)	M (1), G(2)	NO
12.	D (3), R(3)	M (1), G(2)	NO
13.	D (2), R(2), G(2)	M (1), G(2)	NO
14.	D (2), R(3), G(1)	G (3)	NO
15.	D (2), R(3), G(1)	M (1), G(2)	NO
16.	D (2), R(3), G(1)	M (1), G(2)	YES
17.	D (2), R(3), G(1)	M (3)	YES-POSITION 1
18.	D (2), R(3), G(1)	M (3)	YES-POSITION 2
19.	D (2), G(4)	M (1), G(2)	YES
20.	D (2), G(4)	M (3)	YES
21.	D (2), R(3), G(1)	M (1). G(2)	YES
22.	D (2), R(3), G(1),	M (3),	YES-POSITION 3
23.	D (3), R(1), G(1), M (1)	M (1), G(2)	NO
24.	D (3), R(1), G(1), M (1)	M (1), G(1), S (1)	NO

D = ACSR DOG
R = ACSR RABBIT
G = ACSR GOPHER
S = ACSR SQUIRREL
M = ACSR MOLE

The number of sections (node to node), over which a particular conductor has been used, is given within brackets.

3 CONCLUSIONS

A summary of economic comparison of different conductor sizes alongwith line length of conductors, voltage regulation, energy losses, capital cost and net present worth of costs (capital, O&M and losses) is given in the attached table T2-0. The main conclusions from this study are as follows:

- The alternative showing the least cost capital investment (Case 1) is the most expensive solution in terms of net present worth of all costs.

- The least cost solution (Case 24) is based on application of the best conductor (Dog) for about 45% of the line length, and of the smallest conductors (Mole and Squirrel) for about 28% of the line (primarily the T-offs).

- Between two alternatives, one with and another without voltage regulation, the net present worth of costs is reduced in the case of voltage regulation. However, replacement of conductors, generally, is more cost effective than the installation of voltage regulation.

- Application of the best conductor (Dog) on first 1/3rd of the main line and of the cheapest conductors (Mole, Squirrel, Gopher) on the last 1/3rd of the main line and all the branches (Case 13) provides a solution which is close to the least cost solution.

The conductor selection study presented above was based on the following assumptions:

- 15% DF

- Salvage value was ignored

- Demand in year 10 was assumed to be constant throughout the life of the project (30 years)

- 5% O&M was assumed for all conductor types

- Net present worth of capital over the life of the project was calculated using a factor of 1.33

- Net present worth of cost of losses was calculated by dividing the cost by the discount factor

This simplified approach may not yield the correct answers where the differences in total net present worth of costs of different conductor sizes is close to each other.

To understand the impact of the above assumptions, the following changes in methodology were made.

- Salvage value was assumed to be 50% of the capital investment
- Demand forecast for year 1, 5, 10, 15, 20, 25 and 30 were prepared and voltage drop studies including loss calculations was made
- Two types of conductors were studied
  - Conductors based on 10th year demand augmented by voltage regulators upto year 30 and conductor replacement if any
  - Conductors based on 20th year demand augmented by voltage regulators upto year 30
- O&M cost was ignored
- Losses for the intermediate years were extrapolated
- Net present worth of costs was calculated for each year of the project life
- Both 11 kV and 33 kV cases were studied
- Both 30 and 15 year life of project was analysed

Detailed analysis is given in tables T2-25 to T2-32. Voltage drop studies for conductors based on 10th year demand and 20th year demand are given in tables T2-25A to T2-25G and T2-26A to T2-26G. Results of this analysis are summarised below:

	NET PRESENT WORTH OF CONDUCTORS DESIGN BASED ON		COST DIFFERENCE OF NET PRESENT WORTH Rs.
	10th year demand Rs.	20th year demand Rs.	
11 kV LINES			
. 30 year life	1192,839	1303,642	+110,803
. 15 year life	1056,435	1279,784	+223,349
33 kV LINES			
. 30 year life	948,933	1322,641	+373,708
. 15 year life	984,847	1392,361	+407,514

It may be noticed from the above summary that, in all the cases, the conductor based on 10th year demand is more economical over the life of the project. Larger conductor sizes are not economical even if a 30 year life is considered. The choice of larger conductors becomes even less attractive if 33 kV distribution is considered.

The detailed analysis also indicates that there are no changes in the conductor selection using a simplified methodology as against a more rigorous analysis including consideration of salvage value, elimination of O&M costs etc. Changes in the basic parameters can, however, result in other choices than those presented here.

The limited analysis presented here indicates that selection of conductors on the basis of demand in year 20 should result in higher capital investments as well as net present worth of costs over the life of the project. Considerable savings are possible through the adoption of 10th year demand as the basic for design. Choice of conductors is dependent upon a number of factors and detailed studies are recommended in all distribution expansion projects.

TABLE T2-0

SUMMARY OF ECONOMIC COMPARISON OF DIFFERENT CONDUCTOR SIZES
TAKING INTO ACCOUNT VOLTAGE REGULATION AND CAPACITOR APPLICATION (PF = 0.95)
FEEDER LENGTH: Main = 10.05 km. T-offs = 4.01 km. Total = 14.06 km

CASE No.	CONDUCTOR LINE LENGTH (km)						VOLTAGE REGULA-TOR kVA	LOSSES MWH	CAPITAL COST Rs	NET PRESENT WORTH OF OF ALL COSTS Rs.(000)
	D	R	G	S	M	Total				
1	-	-	10.05	-	4.01	14.06	0	153	469,839	2657
2.	-	-	10.05	-	4.01	14.06	140	136	539,834	2528
3	-	10.05	-	-	4.01	14.06	0	74	646,554	1841
4	-	10.05	-	-	4.01	14.06	140	68	716,554	1852
5.	10.05	-	-	-	4.01	14.06	140	36	1,736,032	1950
6	10.05	-	-	-	4.01	14.06	0	40	1,036,032	1904
7	3.00	7.50	-	-	4.01	14.06	0	58	762,834	1785
8	5.37	4.68	-	-	4.01	14.06	0	47	854,635	1756
9.	6.24	3.81	-	-	4.01	14.06	0	43	888,416	1754
10	7.43	2.56	-	-	4.01	14.06	0	40	936,866	1783
11	7.43	2.36	2.76	-	1.25	14.06	0	36	968,980	1768
12	6.24	3.81	2.76	-	1.25	14.06	0	39	920,530	1738
13	5.37	2.12	5.32	-	1.25	14.06	0	46	841,794	1727
14	5.37	3.30	5.39	-	-	14.06	0	42	877,088	1727
15	5.37	3.30	4.14	-	1.25	14.06	0	43	862,543	1720
16	5.37	3.30	4.14	-	1.25	14.06	145	37	958,968	1734
17	5.37	3.30	1.38	-	4.01	14.06	145	40	902,929	1738
18	5.37	3.30	1.38	-	4.01	14.06	97	45	878,929	1765
19	5.37	-	7.44	-	1.25	14.06	145	48	877,015	1809
20.	5.37	-	4.68	-	4.01	14.06	145	53	844,901	1824
21.	5.37	3.30	4.14	-	1.25	14.06	140	39	932,543	1754
22	5.37	3.30	1.38	-	4.01	14.06	140	42	900,429	1758
23.	6.24	1.25	3.94	-	2.63	14.06	0	42	859,453	1704
24.	6.24	1.25	2.56	1.38	2.63	14.06	0	42	855,684	1693

D = DOG
R = RABBIT
G = GOPHER
S = SQUIRREL
M = MOLE

FLOPPY NO. 466 FILE NAME :REMPR5.WK1 /STS

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DESIGN STUDIES OF CONDUCTOR SIZES
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Table T2-1 : Voltage drop studies based on 10th year demand. District Okara, tehsil Okara grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 1 : Without regulator.
Main line : Gopher on all sections. Branch line : Mole on three sections

2 : Voltage drop studies based on 10th year demand. District Okara, tehsil Okara grid station GS-8 11 kV main feeder F1, T-off 1,2,3, Case 2 : With regulator.
Main line : Gopher on all sections. Branch line : Mole on three sections

3 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 3 : Without regulator.
Main line : Rabbit on all sections. Branch line : Mole on three sections

4 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 4 : With regulator.
Main line : Rabbit on all sections. Branch line : Mole on three sections

5 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 5 : With regulator.
Main line : Dog on all sections. Branch line : Mole on three sections

6 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 6 : Without regulator.
Main line : Dog on all sections. Branch line : Mole on three sections

7 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 7 : Without regulator.
Main line : Dog on one section and Rabit on five section. Branch line : Mole on three sections

8 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 8 : Without regulator.
Main line : Dog on two sections and Rabbit on four sections. Branch line : Mole on three sections

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Table T2-9 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS 8, 11 kV main feeder F1, T-off 1,2,3, Case 9 : Without regulator.
Main line : Dog on three section and Rabbit on three section. Branch line : Mole on three sections

10 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 10 : Without regulator.
Main line : Dog on four sections and Rabbit on two sections. Branch line : Mole on three sections

11 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 11 : Without regulator.
Main line : Dog on four sections and Rabbit on two sections. Branch line : Mole on one section and Gopher on two sections

12 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 12 : Without regulator.
Main line : Dog on three section and Rabbit on three sections. Branch line : Mole on one section and Gopher on two sections.

13 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 13 : Without regulator. Main line : Dog on two section, Rabbit on two sections and Gopher on two sections. Branch line : Mole on one section and Gopher on two sections

14 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 14 : Without regulator.
Main line : Dog on two sections, Rabbit on three sections and Gopher on one section. Branch line : Gopher on three sections

15 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 15 : Without regulator.
Maine line : Dog on two sections, Rabbit on three sections and Gopher on one section. Branch line : Mole on one section and Gopher on two sections

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Table T2-16 : Voltage drop studies based on 10th year demand, distric Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 16 : With regulator.
Main line : Dog on two sections, Rabbit on thre sections and Gopher on one section. Branch line : Mole o one section and Gopher on two sections.

17: Voltage drop studies based on 10th year demand, distric Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 17 : With regulator on position 1
Main line : Dog on two sections, Rabbit on thre sections and Gopher on one section. Branch line : Mol on three sections

18 : Voltage drop studies based on 10th year demand, distric Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 18 : With regulator on position 2
Main line : Dog on two sections, Rabbit on three section and Gopher on one section. Branch line : Mole on thre sections

19 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 19 : With regulator.
Main line : Dog on two sections and Gopher on fou sections. Branch line : Mole on one section and Gopher o two sections

20 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 20 : With regulator.
Main line : Dog on two sections and Gopher on fou sections. Branch line : Mole on three sections

21 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 21 : With regulator.
Main line : Dog on two section, Rabbit on three section and Gopher on one section. Branch line : Mole on on section and Gopher on two sections

22 : Voltage drop studies based on 10th year demand, district Okara, Tehsil Okara, Grid station GS-8, 11 kV main feede F1, T-off 1,2,3, Case 22 : With regulator on position 3
Main line : Dog on two sections, Rabbit on three section and Gopher on one section. Branch line : Mole on thre sections

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Table T2-23 : Voltage drop studies based on 10th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 23 : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch Line : Mole on one section and Gopher on two sections.

24 : Voltage drop studies based on 10th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case 24 : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section.

25 : Evaluation of net present worth of cost of 11 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 10th year demand. Project life = 30 years.

25A : Voltage drop studies based on 1st year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case A : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

25B : Voltage drop studies based on 5th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case B : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

25C : Voltage drop studies based on 10th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case C : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

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Table T2-25D : Voltage drop studies based on 15th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case D : Without Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

25E : Voltage drop studies based on 20th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case E : With Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

25F : Voltage drop studies based on 25th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case F : With Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

25G : Voltage drop studies based on 30th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case G : With Regulator.
Main line : Dog on three sections, Rabbit on one section, Gopher on one section and Mole on one section.
Branch line : Mole on one section, Gopher on one sections and Squirrel on one section. (excluding O & M)

26 : Evaluation of net present worth of cost of 11 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 20th year demand. Project life = 30 years.

26A : Voltage drop studies based on 1st year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case H : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

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Table T2-26B : Voltage drop studies based on 5th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case I : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

26C : Voltage drop studies based on 10th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case O : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(including O & M)

26C1: Voltage drop studies based on 10th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case J : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

26D : Voltage drop studies based on 15th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case K : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

26E : Voltage drop studies based on 20th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case L : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

26F : Voltage drop studies based on 25th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case M : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

ANNEX - T2
DESIGN STUDIES OF CONDUCTOR SIZES
LIST OF TABLES

Table T2-26G : Voltage drop studies based on 30th year demand, District Okara, Tehsil Okara, Grid Station GS-8, 11 kV main feeder F1, T-off 1,2,3, Case N : Without Regulator.
Main line : Panther on three sections, Dog on one section, Rabbit on one section and Gopher on one section.
Branch line : Gopher on two section, and Rabbit on one section.(excluding O & M)

27 : Evaluation of net present worth of cost of 11 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 10th year demand. Project life = 15 years.

28 : Evaluation of net present worth of cost of 11 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 20th year demand. Project life = 15 years.

29 : Evaluation of net present worth of cost of 33 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 10th year demand. Project life = 30 years.

30 : Evaluation of net present worth of cost of 33 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 20th year demand. Project life = 30 years.

31 : Evaluation of net present worth of cost of 33 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 10th year demand. Project life = 15 years.

32 : Evaluation of net present worth of cost of 33 kV distribution lines of feeder F1, Grid Station GS-8, District Okara. Design of conductor based on 20th year demand. Project life = 15 years.

TABLE T2-1

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-3
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 1 : WITHOUT REGULATOR. MAIN LINE : GOPHER ON ALL SECTIONS. BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (SLIDER)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	G	4.77	4.77	4.77	10.48		10.48				76.25	70	61320	122640	217600	110205	146573	364173
T1 - A1	2.37	164	1255	G	3.63	3.4	3.4	10.1		10.1				76.12	55	48180	96360	142400	67062	115732	258132
A1 - 206	0.87	226	1101	G	1.16	9.56	9.56	9.88		9.88				67.04	16	14016	28032	136500	31969	42535	229365
206 - X2	1.25	341	875	G	1.32	10.88	10.88	9.65		9.65				53.99	15	13140	26280	175200	45319	61072	236272
X2 - X3	1.18	303	534	G	0.76	11.64	11.64	9.78		9.78				33.18	5	4380	8760	53400	43247	57652	116052
X3 - 254	1.38	231	231	G	0.39	12.03	12.03	9.74		9.74				14.41	1	876	1752	11650	53634	67423	79103
TO-1																					
						3.40	3.4			10.1											
X1 - 226	1.25	164	164	M	0.59	8.99	8.99	10.04		10.04				9.93	1	876	1752	11650	31374	41727	53407
TO-2																					
						10.88	10.88			9.65											
X2 - 207	1.38	341	341	M	1.36	12.24	12.24	9.72		9.72				21.32	6	5256	10512	70080	34637	46067	116147
TO-3																					
						11.64	11.64			9.78											
X3 - 253	1.38	303	303	M	1.21	12.85	12.85	9.66		9.66				19.06	5	4380	8760	58400	34637	46067	104467
TOTAL													0		174	152424	304848	2032320	453834	624873	2657193

CONDUCTOR	ABBR.	RESISTANCE PER KM	11kV VDX PER KM	11kV LINE COST PER KM (Rs)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.653	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-2

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-5
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 2 : WITH REGULATOR. MAIN LINE :GOPHER ON ALL SECTIONS. BRANCH LINE : MOLE ON THREE SECTIONS

FF = 0.55

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (SLT125)	LOSSES kWh	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	6	4.77	4.77	4.77	10.48		10.48											
T1 - X1	2.37	164	1265	6	3.63	8.4	-0.78	10.1	1.01	11.11	140	70000	53100	76.25	70	61320	122640	317600	110205	146573	584173
X1 - 206	0.67	225	1101	6	1.16	9.56	0.38	10.98		10.38				65.2	45	39420	78840	525600	87062	115732	734432
206 - X2	1.25	341	875	6	1.32	10.88	1.7	10.84		10.84				60.94	13	11388	22776	151840	31959	42505	154345
X2 - X3	1.18	303	534	6	0.76	11.64	2.46	10.76		10.76				49.05	12	10512	21024	140160	45919	61072	201232
X3 - 254	1.38	231	231	6	0.39	12.03	2.85	10.72		10.72				30.16	4	3504	7008	46720	42347	57652	104372
														13.1	1	876	1752	11680	59634	67423	79103
TO-1																					
X1 - 226	1.25	164	164	M	0.59	8.40	-0.78	11.04		11.11											
						8.99	-0.19			11.04				9.03	1	876	1752	11680	31874	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	10.88	1.7	10.69		10.84											
						12.24	3.06			10.69				15.39	5	4380	8760	58400	34637	46667	104467
TO-3																					
X3 - 253	1.38	303	303	M	1.21	11.64	2.46	10.63		10.76											
						12.85	3.67			10.63				17.52	4	3504	7008	46720	34637	46667	32787
TOTAL													53100		155	135780	271560	1810400	465634	624573	2528373

CONDUCTOR	ABBR	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.165	0.00022	133068
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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TABLE T2-3

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT GOARA TEHSIL GOARA GRID STATION GS-S
11 kV MAIN FEEDER F1 T-OFF 1.2.3
CASE 3 : WITHOUT REGULATOR MAIN LINE : RABBIT ON ALL SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (CU/ACSR)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	R	2.55	2.56	2.56	11.00		11.00											
T1 - X1	2.37	164	1265	R	1.95	4.51	4.51	10.72		10.72				74.55	33	28903	57816	355440	162957	216733	602173
X1 - 206	0.87	226	1101	R	0.62	5.13	5.13	10.51		10.51				73.15	25	21900	43800	292000	123736	171213	463213
206 - X2	1.25	341	875	R	0.71	5.84	5.84	10.44		10.44				64.03	7	6132	12264	81760	47258	62553	144613
X2 - X3	1.19	303	534	R	0.41	6.25	6.25	10.37		10.37				51.23	6	5256	10512	70080	67899	90306	160386
X3 - 254	1.38	231	231	R	0.21	6.46	6.46	10.33		10.33				31.42	2	1752	3504	23360	64096	85243	108606
								10.31		10.31				12.62	1	876	1752	11680	74960	99637	111377
TO-1																					
X1 - 226	1.25	164	164	M	0.55	4.51	4.51			10.51											
						5.1	5.1	10.45		10.45				9.54	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	5.84	5.84			10.37											
						7.2	7.2	10.23		10.23				20.26	5	4380	8760	58400	34637	46067	104467
TO-3																					
X3 - 253	1.38	303	303	M	1.21	6.25	6.25			10.33											
						7.46	7.46	10.21		10.21				18.04	4	3504	7008	46720	34637	46067	92787
TOTAL													0		84	73584	147168	981120	646554	859917	1841037

CONDUCTOR	ABBR	RESISTANCE PER km	11kV VDX PER km	11kV LINE COST PER km (Rs)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION 6S-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 4 : WITH REGULATOR MAIN LINE : RABBIT ON ALL SECTION SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	R	2.56	2.56	2.56	10.72		10.72				74.55	23	28903	57816	285440	162257	215723	662175
T1 - X1	2.37	164	1265	R	1.55	4.51	-5.04	10.51	1.05	11.56	140	70000	93100	66.5	21	18396	36792	245230	128736	171219	509599
X1 - 206	0.87	226	1101	R	0.62	5.13	-4.42	11.49		11.49				58.23	6	5256	10512	70050	47253	62853	132303
206 - X2	1.25	341	875	R	0.71	5.84	-3.71	11.41		11.41				46.6	5	4380	8760	58400	67899	90306	148706
X2 - X3	1.15	303	534	R	0.41	6.25	-3.3	11.36		11.36				28.57	2	1752	3504	23360	64046	85246	108608
X3 - 254	1.38	231	231	R	0.21	6.46	-3.09	11.34		11.34				12.38	0	0	0	0	74960	99697	99697
TO-1																					
X1 - 226	1.25	164	164	M	0.59	4.51 5.1	-5.04 -4.45	11.49		11.56 11.49				8.67	1	876	1752	11680	31574	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	5.84 7.2	-3.71 -2.35	11.25		11.41 11.25				18.42	5	4380	8760	58400	34637	46467	104467
TO-3																					
X3 - 253	1.38	303	303	M	1.21	6.25 7.46	-3.3 -2.09	11.22		11.36 11.22				16.41	4	3504	7008	46720	34637	46467	92787
TOTAL													93100		77	67452	134904	899360	646554	859317	1852377

CONDUCTOR	ABBR	RESISTANCE PER kM	11kV VDI PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.239	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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TABLE T2-5

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 5 : WITH REGULATOR. MAIN LINE : DOG ON ALL SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LINES)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				75.72	16	14016	28032	186880	279237	371585	558265
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.11	10.72	1.07	11.79	140	75000	33100	65.2	10	8760	17520	116800	220597	299334	503234
X1 - 206	0.87	226	1101	D	0.36	3	-6.75	11.75		11.75				56.34	3	2628	5256	35040	80979	107702	142742
206 - X2	1.25	341	875	D	0.42	3.42	-6.33	11.7		11.7				45.45	3	2628	5256	35040	116349	154744	189784
X2 - X3	1.18	303	534	D	0.24	3.66	-6.09	11.67		11.67				27.31	1	876	1752	11680	109833	146078	157758
X3 - 254	1.38	231	231	D	0.12	3.78	-5.97	11.66		11.66				12.04	0	0	0	0	128449	170837	170837
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	-7.11	11.72		11.79											
						3.23	-6.52			11.72				3.5	1	876	1752	11680	31574	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	3.42	-6.33	11.54		11.7											
						4.78	-4.97			11.54				17.96	4	3504	7008	46720	34637	42067	92787
TO-3																					
X3 - 253	1.38	303	303	M	1.21	3.66	-6.09	11.53		11.67											
						4.87	-4.88			11.53				15.97	3	2628	5256	35040	34637	42067	31107
TOTAL													33100		41	35916	71832	478880	1066092	1373001	1949981

CONDUCTOR	ABBR.	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.163	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.653	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 376

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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TABLE T2-6

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION 66-6
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 6 : WITHOUT REGULATOR MAIN LINE : DOG ON ALL SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

FF = 0.35

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (CALCULATED)	LOSSES kWh	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	15	14016	28032	168000	275227	371305	553265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220557	293394	433554
X1 - 206	0.87	226	1101	D	0.36	3	3	10.68		10.68				62.65	3	2628	5256	35040	80975	107767	143742
206 - X2	1.25	341	875	D	0.42	3.42	3.42	10.64		10.64				49.36	3	2628	5256	35040	116349	154744	189784
X2 - X3	1.18	303	534	D	0.24	3.66	3.66	10.61		10.61				30.53	1	876	1752	11680	108668	146073	157758
X3 - 254	1.38	231	231	D	0.12	3.78	3.78	10.6		10.6				13.24	0	0	0	0	128445	170637	170637
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64 3.23	2.64 3.23	10.66		10.72 10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	3.42 4.78	3.42 4.78	10.5		10.64 10.5				19.74	5	4380	8760	58400	34637	46067	104467
TO-3																					
X3 - 253	1.38	303	303	M	1.21	3.66 4.87	3.66 4.87	10.48		10.61 10.48				17.57	4	3504	7008	46720	34637	46067	92787
TOTAL													0		45	39420	78840	525600	1038092	1378001	1903601

CONDUCTOR	ABBR.	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-7

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT GAGRA TEHSIL GAGRA GRID STATION GS-3
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 7 : WITHOUT REGULATOR. MAIN LINE : DOG ON ONE SECTION AND RABBIT ON FIVE SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (LT+LS)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	R	1.35	3.45	3.45	10.84		10.84				73.72	15	14016	28032	108880	279237	371185	552265
X1 - 206	0.37	226	1101	G	0.62	4.07	4.07	10.63		10.63				72.32	15	21500	43000	252000	128756	171219	463219
206 - X2	1.25	341	975	R	0.71	4.78	4.78	10.56		10.56				63.16	7	5132	12254	31760	47258	62853	144613
X2 - X3	1.18	303	534	R	0.41	5.19	5.19	10.49		10.49				50.63	6	5256	10512	70498	67839	90336	160336
X3 - 254	1.38	231	231	R	0.21	5.4	5.4	10.45		10.45				31.05	2	1752	3504	25200	64756	85243	108658
								10.43		10.43				13.46	0	0	0	0	74560	95697	95697
TO-1																					
X1 - 225	1.25	164	164	M	0.59	3.45	3.45			10.63											
						4.04	4.04	10.57		10.57											
TO-2														9.43	1	376	1752	11680	31574	41727	53407
X2 - 207	1.38	341	341	M	1.36	4.78	4.78			10.45											
						6.14	6.14	10.35		10.35											
TO-3														20.02	5	4380	8760	53400	34637	45767	104467
X3 - 253	1.38	303	303	M	1.21	5.19	5.19			10.45											
						6.4	6.4	10.32		10.32											
														17.34	4	3504	7008	45720	34637	45767	92787
TOTAL													0		56	37816	115632	774000	762834	1014563	1788443

CONDUCTOR	REF	RESISTANCE PER KM	11kV VDI PER KM	11kV LINE COST PER KM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	543.9
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 376

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-8

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-6
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 8 : WITHOUT REGULATOR. MAIN LINE : DOG ON TWO SECTIONS AND RABBIT ON FOUR SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.96

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (CU+ICR)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	186380	279237	371385	556265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220597	293334	433554
X1 - 206	0.87	226	1101	R	0.62	3.26	3.26	10.65		10.65				62.83	7	6132	12264	81760	47258	62853	144613
206 - X2	1.25	341	875	R	0.71	3.97	3.97	10.57		10.57				50.31	6	5256	10512	70080	67899	90306	160386
X2 - X3	1.18	303	534	R	0.41	4.38	4.38	10.53		10.53				30.82	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.38	231	231	R	0.21	4.59	4.59	10.51		10.51				13.36	0	0	0	0	74960	99697	99697
TO-1																					
						2.64	2.64			10.72											
X1 - 226	1.25	164	164	M	0.59	3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.97	3.97			10.57											
X2 - 207	1.38	341	341	M	1.36	5.33	5.33	10.43		10.43				19.87	5	4380	8760	58400	34637	46067	104467
TO-3																					
						4.38	4.38			10.53											
X3 - 253	1.38	303	303	M	1.21	5.59	5.59	10.4		10.4				17.71	4	3504	7008	46720	34637	46067	92787
TOTAL													0		53	40428	92856	619040	854635	1136744	1755784

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-9

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION 66-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 9 : WITHOUT REGULATOR. MAIN LINE : DOG ON THREE SECTIONS AND RABBIT ON THREE SECTIONS. BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (CU+SR)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.84		10.84				73.72	16	14016	28032	186880	279237	371595	558265
X1 - 206	0.87	226	1101	D	0.36	3	3	10.72		10.72				71.71	12	10512	21024	140160	220597	255394	423554
206 - X2	1.25	341	875	R	0.71	3.71	3.71	10.68		10.68				62.65	3	2628	5256	35040	80979	107702	142742
X2 - X3	1.18	303	534	R	0.41	4.12	4.12	10.6		10.6				50.17	6	5256	10512	70080	67899	90306	160386
X3 - 254	1.38	231	231	R	0.21	4.33	4.33	10.56		10.56				30.73	2	1752	3504	23360	64096	85248	108608
								10.54		10.54				13.32	0	0	0	0	74960	99697	99697
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	2.64			10.72											
						3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	M	1.36	3.71	3.71			10.6											
						5.07	5.07	10.46		10.46				19.81	5	4380	8760	58400	34637	46067	104467
TO-3																					
X3 - 253	1.38	303	303	M	1.21	4.12	4.12			10.56											
						5.33	5.33	10.43		10.43				17.65	4	3504	7008	46720	34637	46067	92787
TOTAL													0		49	42924	85848	572320	888416	1181593	1753913

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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TABLE 12-10

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 10 : WITHOUT REGULATOR MAIN LINE : DOG ON FOUR SECTIONS AND RABBIT ON TWO SECTIONS. BRANCH LINE : MOLE ON THREE SECTIONS. PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PV1 Rs.	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PV2 Rs	LINE COST Rs.	PV3 Rs.	TOTAL PVC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	186830	279237	371355	558265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220557	293394	432554
X1 - 206	0.87	226	1101	D	0.36	3	3	10.68		10.68				62.65	3	2628	5256	35040	80979	107702	142742
206 - X2	1.25	341	875	D	0.42	3.42	3.42	10.64		10.64				49.98	3	2628	5256	35040	116349	154744	189784
X2 - X3	1.18	303	534	R	0.41	3.83	3.83	10.6		10.6				30.62	2	1752	3504	23360	64096	85248	106608
X3 - 254	1.38	231	231	R	0.21	4.04	4.04	10.58		10.58				13.27	0	0	0	0	74960	99697	99697
TO-1																					
						2.64	2.64			10.72											
X1 - 226	1.25	164	164	M	0.59	3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.42	3.42			10.64											
X2 - 207	1.38	341	341	M	1.36	4.78	4.78	10.5		10.5				19.74	5	4380	8760	58400	34637	46067	104467
TO-3																					
						3.83	3.83			10.6											
X3 - 253	1.38	303	303	M	1.21	5.04	5.04	10.47		10.47				17.59	4	3504	7008	46720	34637	46067	92787
TOTAL													0		46	40296	80592	537280	936866	1246031	1783311

CONDUCTOR	ABBR	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PVC = Present Worth of Total Cost (PV1+PV2+PV3)

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TABLE T2-11

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 11 : WITHOUT REGULATOR. MAIN LINE : DOG ON FOUR SECTIONS AND RABBIT ON TWO SECTIONS. BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS.

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.34		10.34				73.72	16	14016	28032	136850	279237	371385	558265
X1 - 206	0.87	226	1101	D	0.36	3	3	10.72		10.72				71.71	12	10512	21024	140160	220597	293394	433554
206 - X2	1.25	341	875	D	0.42	3.42	3.42	10.63		10.63				62.65	3	2628	5256	35040	80975	107702	142742
X2 - X3	1.18	303	534	R	0.41	3.83	3.83	10.64		10.64				49.93	3	2628	5256	35040	116343	154744	189784
X3 - 254	1.38	231	231	R	0.21	4.04	4.04	10.6		10.6				30.62	2	1752	3504	23360	64096	85248	108608
								10.58		10.58				13.27	0	0	0	0	74960	99697	99697
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	2.64			10.72											
						3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	G	0.57	3.42	3.42			10.64											
						3.99	3.99	10.52		10.58				13.59	2	1752	3504	23360	50694	67423	90783
TO-3																					
X3 - 253	1.38	303	303	G	0.51	3.83	3.83			10.6											
						4.34	4.34	10.55		10.55				17.45	2	1752	3504	23360	50694	67423	90783
TOTAL													0		41	35916	71832	478880	968880	1288743	1767623

CONDUCTOR	AEER	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs)
FANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

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TABLE T2-12

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 12 : WITHOUT REGULATOR. MAIN LINE : DOG ON THREE SECTIONS AND RABBIT ON THREE SECTIONS. BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS. PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs	CURRENT Amps	LOSSES kW (SLITTER)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	168380	279237	371365	558265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220597	293394	433554
X1 - 206	0.97	226	1101	D	0.36	3	3	10.68		10.68				62.65	3	2628	5256	35040	80979	107702	142742
206 - X2	1.25	341	875	R	0.71	3.71	3.71	10.6		10.6				50.17	6	5256	10512	70080	67899	90306	160386
X2 - X3	1.18	303	534	R	0.41	4.12	4.12	10.56		10.56				30.73	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.38	231	231	R	0.21	4.33	4.33	10.54		10.54				13.32	0	0	0	0	74960	99697	99697
TO-1																					
						2.64	2.64			10.72											
X1 - 226	1.25	164	164	M	0.53	3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.71	3.71			10.6											
X2 - 207	1.38	341	341	G	0.57	4.28	4.28	10.54		10.54				19.66	2	1752	3504	23360	50694	67423	90783
TO-3																					
						4.12	4.12			10.56											
X3 - 253	1.38	303	303	G	0.51	4.63	4.63	10.51		10.51				17.52	2	1752	3504	23360	50694	67423	90783
TOTAL													0		44	38544	77088	513920	920530	1224305	1738225

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-13

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 13 : WITHOUT REGULATOR. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON TWO SECTIONS AND GOPHER ON TWO SECTIONS BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (SLITER)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	186880	279237	371335	558265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220597	293334	433554
X1 - 206	0.97	226	1101	R	0.62	3.26	3.26	10.65		10.65				62.83	7	6132	12264	81760	47258	62853	144613
206 - X2	1.25	341	875	R	0.71	3.97	3.97	10.57		10.57				50.31	6	5256	10512	70080	67899	90306	160386
X2 - X3	1.18	303	534	G	0.76	4.73	4.73	10.49		10.49				30.94	5	4380	8760	58400	43347	57652	116052
X3 - 254	1.38	231	231	G	0.39	5.12	5.12	10.45		10.45				13.43	1	876	1752	11680	50694	67423	79103
TO-1																					
						2.64	2.64			10.72											
X1 - 226	1.25	164	164	M	0.53	3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.97	3.97			10.57											
X2 - 207	1.38	341	341	G	0.57	4.54	4.54	10.51		10.51				19.72	2	1752	3504	23360	50694	67423	90783
TO-3																					
						4.73	4.73			10.49											
X3 - 253	1.38	303	303	G	0.51	5.24	5.24	10.44		10.44				17.64	2	1752	3504	23360	50694	67423	90783
TOTAL													0		52	45552	91104	607360	841794	1119556	1726946

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VDX PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-14

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-6
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 14 : WITHOUT REGULATOR MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (CU+IRON)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
G - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	124440	279257	371719	556255
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	223557	250234	433554
X1 - 206	0.87	226	1101	R	0.62	3.26	3.26	10.65		10.65				62.33	7	6132	12264	81760	47258	62353	144613
206 - X2	1.25	341	875	R	0.71	3.97	3.97	10.57		10.57				50.31	6	5256	10512	70080	67899	90486	160386
X2 - X3	1.19	303	534	R	0.41	4.38	4.38	10.53		10.53				30.82	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.39	231	231	G	0.39	4.77	4.77	10.49		10.49				13.38	1	876	1752	11680	50694	67423	79103
TO-1																					
						2.64	2.64			10.72											
X1 - 226	1.25	164	164	G	0.25	2.89	2.89	10.69		10.69				9.32	0	0	0	0	45319	61072	61072
TO-2																					
						3.97	3.97			10.57											
X2 - 207	1.38	341	341	G	0.57	4.54	4.54	10.51		10.51				19.72	2	1752	3504	23360	50694	67423	90783
TO-3																					
						4.38	4.38			10.53											
X3 - 253	1.39	303	303	G	0.51	4.89	4.89	10.48		10.48				17.57	2	1752	3504	23360	50694	67423	90783
TOTAL													0		48	42048	84096	560640	877068	1166527	1727167

CONDUCTOR	ABBR	RESISTANCE PER kM	11kV VDX PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-15

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA . GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 15 : WITHOUT REGULATOR. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS. PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PV1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PV2 Rs	LINE COST Rs	PV3 Rs	TOTAL PVC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	186880	279237	371365	552265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220597	293934	433554
X1 - 206	0.87	226	1101	R	0.62	3.26	3.26	10.65		10.65				62.83	7	6132	12264	81760	47258	62853	144613
206 - X2	1.25	341	875	R	0.71	3.97	3.97	10.57		10.57				50.31	6	5256	10512	70080	67839	90306	163386
X2 - X3	1.18	303	534	R	0.41	4.38	4.38	10.53		10.53				30.92	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.38	231	231	G	0.39	4.77	4.77	10.49		10.49				13.38	1	876	1752	11680	50634	67423	79103
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	2.64	10.66		10.72				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	G	0.57	3.97	3.97	10.51		10.57				19.72	2	1752	3504	23360	50634	67423	90783
TO-3																					
X3 - 253	1.38	303	303	G	0.51	4.38	4.38	10.49		10.53				17.57	2	1752	3504	23360	50634	67423	90783
TOTAL													0		49	42924	85848	572320	862543	1147182	1719502

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PVC = Present Worth of Total Cost (PV1+PV2+PV3)

TABLE T2-16

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION SS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 16 : WITH REGULATOR. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION: BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS. PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PV1 Rs.	CURRENT Amps	LOSSES kV (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PV2 Rs.	LINE COST Rs.	PV3 Rs	TOTAL PWC Rs.
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	-8.35	11.60		11.00											
T1 - X1	2.27	164	1265	D	1.14	2.64	-7.21	10.94	1.08	11.92	145	72500	96425	67.04	14	12264	24528	163520	279237	371335	631330
X1 - 206	0.87	226	1101	R	0.62	3.26	-6.59	11.78		11.78				65.26	10	8760	17520	116800	220537	293334	410134
206 - X2	1.25	341	875	R	0.71	3.97	-5.88	11.71		11.71				57.14	6	5256	10512	70080	47258	62853	132933
X2 - X3	1.13	303	534	R	0.41	4.38	-5.47	11.63		11.63				45.72	5	4380	8760	58400	67899	90306	148706
X3 - 254	1.38	231	231	G	0.39	4.77	-5.08	11.58		11.58				28.02	2	1752	3504	23360	64096	85248	108608
								11.53		11.53				12.18	1	876	1752	11680	50694	67423	79103
TO-1																					
X1 - 225	1.25	164	164	M	0.59	2.64	-7.21			11.92											
						3.23	-6.62	11.85		11.85											
TO-2														9.41	1	876	1752	11680	31374	41727	53407
X2 - 207	1.38	341	341	G	0.57	3.97	-5.88			11.63											
						4.54	-5.31	11.56		11.56											
TO-3														17.93	2	1752	3504	23360	50694	67423	90783
X3 - 253	1.38	303	303	G	0.51	4.38	-5.47			11.58											
						4.89	-4.96	11.52		11.52											
														15.98	1	876	1752	11680	50694	67423	79103
TOTAL																					
													96425		42	36792	73584	490560	862543	1147192	1734167

CONDUCTOR	AEER	RESISTANCE PER KM	11kV VDX PER KM	11kV LINE COST PER KM (Rs)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00045	54319
GOPHER	G	1.330	0.00021	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PV1+PV2+PV3)

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TABLE T2-17

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8

11 kV MAIN FEEDER F1 . T-OFF 1,2,3

CASE 17 : WITH REGULATOR ON POSITION 1. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PV1 Rs	CURRENT Amps	LOSSES kW (CU+IR)	LOSSES kWH	LOSSES COST Rs	PV2 Rs	LINE COST Rs	PV3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	-8.35	10.84	1.08	11.92	145	72500	96425	67.04	14	12264	24528	163520	279237	371385	631330
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.21	11.73		11.78				65.26	10	8760	17520	116800	223597	293334	410194
X1 - 206	0.87	226	1101	R	0.62	3.26	-6.53	11.71		11.71				57.14	6	5256	10512	70080	47258	62853	132933
206 - X2	1.25	341	875	R	0.71	3.97	-5.88	11.63		11.63				45.72	5	4380	8760	58400	67899	90306	148706
X2 - X3	1.18	303	534	R	0.41	4.38	-5.47	11.58		11.58				28.02	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.38	231	231	G	0.39	4.77	-5.08	11.53		11.53				12.18	1	876	1752	11680	50634	67423	79103
TO-1																					
						2.64	-7.21			11.92											
X1 - 226	1.25	164	164	M	0.59	3.23	-6.62	11.85		11.85				8.41	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.97	-5.88			11.63											
X2 - 207	1.38	341	341	M	1.36	5.33	-4.52	11.47		11.47				18.07	4	3504	7008	46720	34637	46067	92787
TO-3																					
						4.38	-5.47			11.58											
X3 - 253	1.38	303	303	M	1.21	5.59	-4.26	11.44		11.44				16.1	3	2628	5256	35040	34637	46067	81107
TOTAL													96425		46	40296	80592	537280	830429	1104470	1738175

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.163	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25059

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PV1+PV2+PV3)

TABLE T2-18

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-6
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 18 : WITH REGULATOR ON POSITION 2. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.55

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (SLIPER)	LOSSES kWh	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.84		10.84											
X1 - 206	0.87	226	1101	R	0.62	3.26	3.26	10.72		10.72				73.72	16	14016	28032	166880	279237	371385	558265
206 - X2	1.25	341	875	R	0.71	3.97	-5.64	10.65		10.65				71.71	12	10512	21024	140160	220597	293394	433554
X2 - X3	1.16	303	534	R	0.41	4.38	-5.23	10.57	1.06	11.63	97	48500	64505	62.83	7	6132	12264	81760	47258	62853	144613
X3 - 254	1.38	231	231	G	0.39	4.77	-4.84	11.56		11.58				45.72	5	4380	8760	58400	67899	90306	213211
								11.53		11.53				28.02	2	1752	3504	23360	64096	85246	108608
TO-1														12.15	1	876	1752	11680	50694	67423	79103
X1 - 225	1.25	164	164	M	0.59	2.64	2.64			10.72											
						3.23	3.23	10.66		10.66											
TO-2														9.35	1	876	1752	11680	31374	41727	53407
X2 - 207	1.38	341	341	M	1.36	3.97	-5.64			11.63											
						5.33	-4.28	11.47		11.47											
TO-3														18.07	4	3504	7008	46720	34637	46067	92767
X3 - 253	1.38	303	303	M	1.21	4.38	-5.23			11.58											
						5.59	-4.02	11.44		11.44											
														16.1	3	2628	5256	35040	34637	46067	81107
TOTAL													64505		51	44676	89352	595680	830429	1104470	1764655

CONDUCTOR	ABBR	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-19

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 19 : WITH REGULATOR. MAIN LINE : DOG ON TWO SECTIONS AND GOPHER ON FOUR SECTIONS. BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS.

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	-3.35	10.84	1.08	11.92	145	72500	96425	67.04	14	12264	24528	163520	279237	371385	631330
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.21	11.78		11.78				65.26	10	8760	17520	116800	220597	293394	410194
X1 - 206	0.87	226	1101	G	1.16	3.8	-6.05	11.64		11.64				57.48	11	9636	19272	128480	31959	42505	170985
206 - X2	1.25	341	875	G	1.32	5.12	-4.73	11.49		11.49				46.28	11	9636	19272	128480	45919	61072	189552
X2 - X3	1.18	303	534	G	0.75	5.88	-3.97	11.4		11.4				28.47	4	3504	7008	46720	43347	57652	104372
X3 - 254	1.38	231	231	G	0.39	6.27	-3.58	11.36		11.36				12.36	1	876	1752	11680	50694	57423	79103
TO-1																					
						2.64	-7.21			11.92											
X1 - 226	1.25	164	164	M	0.59	3.23	-6.62	11.85		11.85				8.41	1	876	1752	11680	31374	41727	53407
TO-2																					
						5.12	-4.73			11.49											
X2 - 207	1.38	341	341	G	0.57	5.69	-4.16	11.42		11.42				18.15	2	1752	3504	23360	50694	67423	90783
TO-3																					
						5.58	-3.97			11.4											
X3 - 253	1.38	303	303	G	0.51	6.09	-3.46	11.34		11.34				16.24	1	876	1752	11680	50694	67423	79103
TOTAL													96425		55	48180	96360	642400	804515	1070004	1808829

CONDUCTOR	ABBR	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-20

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION 66-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 20 : WITH REGULATOR. MAIN LINE : DOG ON TWO SECTIONS AND GOPHER ON FOUR SECTIONS BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	-8.35	11.00		11.00				67.04	14	12264	24528	163520	279237	371385	631330
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.21	10.84	1.08	11.92	145	72500	96425	65.26	10	8760	17520	116800	220597	293594	410194
X1 - 206	0.87	226	1101	G	1.16	3.8	-6.05	11.78		11.78				57.48	11	9636	19272	128480	31959	42505	170985
206 - X2	1.25	341	875	G	1.32	5.12	-4.73	11.64		11.64				46.28	11	9636	19272	128480	45919	61072	189552
X2 - X3	1.18	303	534	G	0.76	5.88	-3.97	11.49		11.49				28.47	4	3504	7008	46720	43347	57652	104372
X3 - 254	1.38	231	231	G	0.39	6.27	-3.58	11.4		11.4				12.36	1	876	1752	11680	50694	67425	79103
								11.36		11.36											
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	-7.21			11.92											
						3.23	-6.62	11.85		11.85											
TO-2														8.41	1	876	1752	11680	31374	41727	53407
X2 - 207	1.38	341	341	M	1.36	5.12	-4.73			11.49											
						6.48	-3.37	11.33		11.33											
TO-3														18.29	4	3504	7008	46720	34637	46067	92787
X3 - 253	1.38	303	303	M	1.21	5.58	-3.97			11.4											
						6.79	-2.76	11.26		11.26											
														16.35	4	3504	7008	46720	34637	46067	92787
TOTAL													96425		60	52560	105120	700800	772401	1027292	1824517

CONDUCTOR	ABBR.	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-21

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 21 : WITH REGULATOR. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION. BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs.	CURRENT Amps	LOSSES kW (3I²R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs.	PW3 Rs.	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.84		10.84				73.72	16	14016	28032	186880	279237	371595	558265
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.11	10.72	1.07	11.79	140	70000	93100	65.2	10	8760	17520	116800	220597	293994	503294
X1 - 206	0.87	226	1101	R	0.62	3.26	-6.49	11.72		11.72				57.09	6	5256	10512	70080	47258	62953	132933
206 - X2	1.25	341	875	R	0.71	3.97	-5.78	11.64		11.64				45.68	5	4380	8760	58400	67899	90306	148706
X2 - X3	1.18	303	534	R	0.41	4.38	-5.37	11.59		11.59				28	2	1752	3504	23360	64096	85248	108608
X3 - 254	1.38	231	231	G	0.39	4.77	-4.98	11.54		11.54				12.16	1	876	1752	11680	50694	67423	79103
TO-1																					
						2.64	-7.11			11.79											
X1 - 226	1.25	164	164	M	0.59	3.23	-6.52	11.72		11.72				8.5	1	876	1752	11680	31374	41727	53407
TO-2																					
						3.97	-5.78			11.64											
X2 - 207	1.38	341	341	G	0.57	4.54	-5.21	11.57		11.57				17.91	2	1752	3504	23360	50694	67423	90783
TO-3																					
						4.38	-5.37			11.59											
X3 - 253	1.38	303	303	G	0.51	4.89	-4.86	11.53		11.53				15.97	1	876	1752	11680	50694	67423	79103
TOTAL													93100		44	38544	77088	513920	862543	1147182	1754202

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-22

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION 66-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 22 : WITH REGULATOR ON POSITION 3. MAIN LINE : DOG ON TWO SECTIONS, RABBIT ON THREE SECTIONS AND GOPHER ON ONE SECTION BRANCH LINE : MOLE ON THREE SECTIONS

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	-7.11	10.84		10.54				73.72	16	14016	29032	186880	279237	371385	558265
X1 - 206	0.87	22[illegible]	1101	R	0.62	3.26	-6.49	10.72	1.07	11.79	140	70000	93100	65.2	10	8760	17520	116800	220597	293394	503294
206 - X2	1.25	341	875	R	0.71	3.97	-5.78	11.72		11.72				57.09	6	5256	10512	70080	47258	62653	132933
X2 - X3	1.18	303	534	R	0.41	4.38	-5.37	11.64		11.64				45.65	5	4380	8760	58400	67899	90306	148706
X3 - 254	1.38	231	231	G	0.39	4.77	-4.98	11.59		11.59				23	2	1752	3504	23360	64096	85248	108608
								11.54		11.54				12.16	1	876	1752	11680	50634	67423	79103
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	-7.11			11.79											
						3.23	-6.52	11.72		11.72											
TO-2														8.5	1	876	1752	11680	31374	41727	53407
X2 - 207	1.38	341	341	M	1.36	3.97	-5.78			11.64											
						5.33	-4.42	11.48		11.48											
TO-3														18.05	4	3504	7008	46720	34637	46067	92787
X3 - 253	1.38	303	303	M	1.21	4.38	-5.37			11.59											
						5.59	-4.16	11.45		11.45											
														16.08	3	2628	5256	35040	34637	46067	81107
TOTAL													93100		48	42048	84096	560640	830429	1104470	1758210

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-23

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 23 : WITHOUT REGULATOR. MAIN LINE : DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION AND GOPHER ON TWO SECTIONS.

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PV1 Rs	CURRENT Amps	LOSSES kV (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PV2 Rs	LINE COST Rs	PV3 Rs	TOTAL PVC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	D	1.5	1.5	1.5	10.94		10.94				73.72	16	14016	28032	186880	279237	371365	556265
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.72		10.72				71.71	12	10512	21024	140160	220597	293394	433554
X1 - 206	0.87	225	1101	D	0.36	3	3	10.68		10.68				62.65	3	2628	5256	35040	80979	107702	142742
206 - X2	1.25	341	875	R	0.71	3.71	3.71	10.6		10.6				50.17	6	5256	10512	70080	67939	90306	160386
X2 - X3	1.19	303	534	G	0.76	4.47	4.47	10.57		10.52				30.85	4	3504	7008	46720	43247	57652	104372
X3 - 254	1.38	231	231	M	0.92	5.39	5.39	10.42		10.42				13.47	2	1752	3504	23360	34837	46067	69427
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64 3.23	2.64 3.23	10.66		10.72 10.66				9.35	1	876	1752	11680	31574	41727	53407
TO-2																					
X2 - 207	1.38	341	341	G	0.57	3.71 4.28	3.71 4.28	10.54		10.6 10.54				19.66	2	1752	3504	23360	50694	67023	90783
TO-3																					
X3 - 253	1.38	303	303	G	0.51	4.47 4.98	4.47 4.98	10.47		10.52 10.47				17.59	2	1752	3504	23360	50694	67023	90783
TOTAL													0		48	42048	84096	560640	559458	1143079	1703719

CONDUCTOR	ABBR.	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PVC = Present Worth of Total Cost (PV1+PV2+PV3)

TABLE T2-24

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 24 : WITHOUT REGULATOR MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION; GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION,
GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION.

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.84		10.84				73.72	16	14016	28032	186880	279237	371385	558265
X1 - 206	0.87	226	1101	D	0.36	3	3	10.72		10.72				71.71	12	10512	21024	140160	220597	293394	433554
206 - X2	1.25	341	875	R	0.71	3.71	3.71	10.68		10.68				62.65	3	2628	5256	35040	80979	107702	142742
X2 - X3	1.18	303	534	G	0.76	4.47	4.47	10.6		10.6				50.17	6	5256	10512	70080	67899	90306	160386
X3 - 254	1.38	231	231	M	0.92	5.39	5.39	10.52		10.52				30.85	4	3504	7008	46720	43347	57652	104372
								10.42		10.42				13.47	2	1752	3504	23360	34637	46067	69427
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	2.64			10.72											
						3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	41727	53407
TO-2																					
X2 - 207	1.38	341	341	G	0.57	3.71	3.71			10.6											
						4.28	4.28	10.54		10.54				19.66	2	1752	3504	23360	50694	67423	90783
TO-3																					
X3 - 253	1.38	303	303	S	0.61	4.47	4.47			10.52											
						5.08	5.08	10.46		10.46				17.6	2	1752	3504	23360	46920	62404	85764
TOTAL													0		46	42048	84096	560640	855684	1139060	1698700

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VDX PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 875

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-25

EVALUATION OF NET PRESENT WORTH OF COST OF 11 KV DISTRIBUTION LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 10TH YEAR DEMAND
PROJECT LIFE = 30 Years

YEAR	COST Rs			PRESENT WORTH OF COSTS Rs		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	855,684	0	3,386	744,073	2,944	747,017
2	0	0	6,473	0	4,895	4,895
3	0	0	12,374	0	8,136	8,136
4	0	0	23,655	0	13,525	13,525
5	0	0	45,222	0	22,483	22,483
6	0	0	51,196	0	22,133	22,133
7	0	0	57,959	0	21,789	21,789
8	0	0	65,615	0	21,450	21,450
9	0	0	74,283	0	21,116	21,116
10	0	0	84,096	0	20,787	20,787
11	0	0	95,636	0	20,556	20,556
12	0	0	106,760	0	20,328	20,328
13	0	0	123,685	0	20,102	20,102
14	0	0	140,658	0	19,879	19,879
15	0	0	159,962	0	19,658	19,658
16	0	0	175,004	0	18,702	18,702
17	0	0	191,461	0	17,792	17,792
18	0	0	209,466	0	16,926	16,926
19	0	0	229,164	0	16,102	16,102
20	0	103,500	250,714	6,324	15,319	21,643
21	0	0	259,815	0	13,804	13,804
22	0	0	269,247	0	12,439	12,439
23	0	0	279,021	0	11,210	11,210
24	0	0	289,150	0	10,101	10,101
25	0	9,500	299,646	289	9,103	9,391
26	0	0	309,455	0	8,174	8,174
27	0	0	319,585	0	7,341	7,341
28	0	0	330,047	0	6,592	6,592
29	0	0	340,851	0	5,920	5,920
30	0	9,500	352,010	143	5,316	5,460
SALVAGE VALUE	427,842	61,250	0	7,387	0	7,387
			TOTAL NPV	758,216	434,623	1,192,839

AT TABT2-25.WK1

TABLE T2-25A

VOLTAGE DROP STUDIES BASED ON 1ST YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA GRID STATION GS-6
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE A : WITHOUT REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs.
MAIN																					
0																					
0 - T1	3	10	263	D	0.3	0.3	0.3	11.00		11.00											
T1 - X1	2.37	33	253	D	0.23	0.53	0.53	10.97		10.97				14.57	0.642	562	1124	7493	279337	279337	286730
X1 - 206	0.87	45	220	D	0.07	0.6	0.6	10.94		10.94				14.05	0.472	413	826	5507	220597	220597	226104
206 - X2	1.25	68	175	R	0.14	0.74	0.74	10.93		10.93				12.23	0.131	115	230	1533	80979	80979	82512
X2 - X3	1.18	61	107	G	0.15	0.89	0.89	10.91		10.91				9.75	0.235	206	412	2747	67833	67899	70646
X3 - 254	1.38	46	46	M	0.18	1.07	1.07	10.89		10.89				5.97	0.168	147	294	1960	43347	43347	45307
TO-1								10.87		10.87				2.57	0.088	77	154	1027	34637	34637	35664
X1 - 226	1.25	33	33	M	0.12	0.53 0.65	0.53 0.65	10.93		10.94 10.93				1.83	0.041	36	72	480	31374	31374	31854
TO-2																					
X2 - 207	1.38	68	68	G	0.11	0.74 0.85	0.74 0.85	10.9		10.91 10.9				3.79	0.079	69	138	920	50694	50694	51614
TO-3																					
X3 - 253	1.38	61	61	S	0.12	0.89 1.01	0.89 1.01	10.88		10.89 10.88				3.41	0.078	68	136	907	46920	46920	47827
TOTAL													0		1.934	1693	3386	22574	855684	855684	878258

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40691
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00250	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-25B

VOLTAGE DROP STUDIES BASED ON 5TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-B
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE B : WITHOUT REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	36	947	O	1.00	1.00	1.00	10.88		10.88				52.9	8.462	7413	14826	98840	279237	279237	378077
T1 - X1	2.37	118	911	D	0.82	1.9	1.9	10.79		10.79				51.31	6.289	5509	11018	73453	220597	220597	294050
X1 - 206	0.87	163	793	D	0.26	2.16	2.16	10.76		10.76				44.79	1.759	1541	3082	20547	80979	80979	101526
206 - X2	1.25	246	630	R	0.51	2.67	2.67	10.71		10.71				35.75	3.158	2766	5532	36880	67899	67899	104779
X2 - X3	1.18	218	384	G	0.55	3.22	3.22	10.65		10.65				21.91	2.26	1980	3960	26400	43347	43347	69747
X3 - 254	1.38	166	166	M	0.66	3.88	3.88	10.58		10.58				9.54	1.217	1066	2132	14213	34637	34637	48850
TO-1																					
						1.90	1.9			10.79											
X1 - 226	1.25	118	118	M	0.43	2.33	2.33	10.74		10.74				6.68	0.541	474	948	6320	31374	31374	37694
TO-2																					
						2.67	2.67			10.71											
X2 - 207	1.38	246	246	G	0.41	3.08	3.08	10.67		10.67				14.01	1.081	947	1894	12627	50634	50634	63261
TO-3																					
						3.22	3.22			10.65											
X3 - 253	1.38	218	218	S	0.44	3.66	3.66	10.6		10.6				12.5	1.045	915	1830	12200	46920	46920	59120
TOTAL													0		25.312	22611	45222	301480	855684	855684	1157164

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2- 25C

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE C : WITHOUT REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0																					
0 - T1	3	50	1315	D	1.5	1.5	1.5	11.00		11.00											
T1 - X1	2.37	164	1265	D	1.14	2.64	2.64	10.84		10.84				73.72	16	14016	28032	168288	279237	279237	466117
X1 - 206	0.87	226	1101	D	0.36	3	3	10.72		10.72				71.71	12	10512	21024	140160	220597	220597	360757
206 - X2	1.25	341	875	R	0.71	3.71	3.71	10.68		10.68				62.65	3	2628	5256	35040	80979	80979	116019
X2 - X3	1.18	303	534	G	0.76	4.47	4.47	10.6		10.6				50.17	6	5256	10512	70080	67899	67899	137979
X3 - 254	1.38	231	231	M	0.92	5.39	5.39	10.52		10.52				30.85	4	3504	7008	46720	43347	43347	90067
								10.42		10.42				13.47	2	1752	3504	23360	34637	34637	57997
TO-1																					
X1 - 226	1.25	164	164	M	0.59	2.64	2.64			10.72											
						3.23	3.23	10.66		10.66				9.35	1	876	1752	11680	31374	31374	43054
TO-2																					
X2 - 207	1.38	341	341	G	0.57	3.71	3.71			10.6											
						4.28	4.28	10.54		10.54				19.66	2	1752	3504	23360	50694	50694	74054
TO-3																					
X3 - 253	1.38	303	303	S	0.61	4.47	4.47			10.52											
						5.08	5.08	10.46		10.46				17.6	2	1752	3504	23360	45920	45920	70280
TOTAL													0		48	42048	84096	560640	855684	855684	1416324

CONDUCTOR	ABBR.	RESISTANCE PER kM	: % VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133888
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36736
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-25D

VOLTAGE DROP STUDIES BASED ON 15TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE D : WITHOUT REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE kVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	67	1750	D	2	2	2	10.78		10.78				98.66	29.435	25785	51570	343800	279237	279237	623037
T1 - X1	2.37	218	1683	D	1.52	3.52	3.52	10.62		10.62				96.31	23.155	19411	38822	258813	220597	220597	479410
X1 - 206	0.87	301	1465	D	0.49	4	4	10.57		10.57				84.23	6.222	5450	10900	72667	00979	00979	153646
206 - X2	1.25	454	1164	R	0.95	4.95	4.95	10.47		10.47				67.56	11.25	9881	19762	131747	67899	67899	199646
X2 - X3	1.18	403	710	G	1.01	5.96	5.96	10.36		10.36				41.65	6.167	7154	14308	95387	43347	43347	138734
X3 - 254	1.38	307	307	M	1.23	7.19	7.19	10.23		10.23				16.24	4.45	3898	7796	51973	34637	34637	86610
TO-1																					
X1 - 226	1.25	218	218	M	0.79	3.52 4.31	3.52 4.31	10.54		10.62 10.54				12.57	1.914	1677	3354	22360	31374	31374	53734
TO-2																					
X2 - 207	1.38	454	454	G	0.76	4.95 5.71	4.95 5.71	10.39		10.47 10.39				26.55	3.881	3400	6800	45333	50634	50634	96027
TO-3																					
X3 - 253	1.38	403	403	S	0.81	5.96 6.77	5.96 6.77	10.28		10.36 10.28				23.82	3.756	3325	6650	44333	46920	46920	91253
TOTAL													0		91.304	79981	159962	1066413	855684	855684	1922097

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs)
PANTHER	P	0.168	0.00022	133888
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40691
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00250	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-25E

VOLTAGE DROP STUDIES BASED ON 20TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA . GRID STATION GS-8 .
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE E : WITH REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION. BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION. (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PV1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PV2 Rs	LINE COST Rs.	PV3 Rs	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	56	2248	D	2.56	2.56	2.56	10.72		10.72				127.44	49.113	43023	86046	573640	279237	279237	852877
T1 - X1	2.37	260	2162	D	1.35	4.51	4.51	10.51		10.51				125.01	37.333	32704	65408	436053	220597	220597	656650
X1 - 206	0.87	386	1882	D	0.62	5.13	-4.36	10.44	1.04	11.48	207	103500	137655	99.63	8.785	7626	15252	101680	80979	80979	320314
206 - X2	1.25	583	1496	R	1.22	6.35	-3.14	11.34		11.34				80.17	15.883	13914	27828	185520	67899	67899	253419
X2 - X3	1.18	518	913	G	1.3	7.65	-1.84	11.19		11.19				49.58	11.574	10139	20278	135187	43347	43347	178534
X3 - 254	1.38	395	395	M	1.58	9.23	-0.26	11.01		11.01				21.8	6.357	5569	11138	74253	34637	34637	108890
TO-1																					
						4.51	4.51			10.51											
X1 - 226	1.25	280	280	M	1.02	5.53	5.53	10.4		10.4				16.36	3.243	2841	5682	37880	31374	31374	69254
TO-2																					
						6.35	-3.14			11.34											
X2 - 207	1.38	583	583	G	0.97	7.32	-2.17	11.23		11.23				31.55	5.481	4801	9602	64013	50634	50634	114707
TO-3																					
						7.65	-1.84			11.19											
X3 - 253	1.38	518	518	S	1.04	8.69	-0.8	11.07		11.07				28.44	5.411	4740	9480	63200	46920	46920	110120
TOTAL													137655		143.1	125357	250714	1671426	855684	855684	2664765

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40691
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PV1+PV2+PV3)

TABLE T2-25p

VOLTAGE DROP STUDIES BASED ON 25TH YEAR DEMAND. DISTRICT OKARA TEHSIL OKARA GRID STATION GS-B
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE F : WITH REGULATOR. MAIN LINE :DOG ON THREE SECTIONS. RABBIT ON ONE SECTION. GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION. (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs.	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs.	LINE COST Rs.	PW3 Rs.	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	93	2446	D	2.79	2.79	2.79	10.69		10.63				139.35	58.469	51219	102438	682920	279237	279237	962157
T1 - X1	2.37	305	2353	D	2.12	4.91	4.91	10.46		10.46				136.71	44.649	39113	78226	521507	220597	220597	742104
X1 - 206	0.87	420	2048	D	0.68	5.59	-3.86	10.39	1.04	11.43	226	113000	150250	108.89	10.398	9109	18218	121453	80979	80979	352722
206 - X2	1.25	634	1628	R	1.32	6.91	-2.54	11.26		11.28				87.71	19.011	16654	33308	222053	67899	67899	289952
X2 - X3	1.18	564	994	G	1.42	8.33	-1.12	11.12		11.12				54.32	13.892	12169	24332	162253	43347	43347	205600
X3 - 254	1.38	430	430	M	1.72	10.05	0.6	10.93		10.93				23.91	7.647	6699	13398	89320	34637	34637	123957
TO-1																					
X1 - 226	1.25	305	305	M	1.11	4.91	4.91	10.34		10.46				17.93	3.890	3412	6824	45493	31374	31374	76867
						6.02	6.02			10.34											
TO-2																					
X2 - 207	1.38	634	634	G	1.06	6.91	-2.54	11.16		11.28				34.52	6.561	5747	11494	76627	50694	50694	127321
						7.97	-1.48			11.16											
TO-3																					
X3 - 253	1.38	564	564	S	1.13	8.33	-1.12	10.99		11.12				31.19	6.588	5701	11402	76013	46920	46920	122933
						9.46	0.01			10.99											
TOTAL													150250		171.03	149823	299646	1997639	855684	855684	3003613

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25899

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2- 25G

VOLTAGE DROP STUDIES BASED ON 30TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA . GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE 6 : WITH REGULATOR. MAIN LINE :DOG ON THREE SECTIONS, RABBIT ON ONE SECTION, GOPHER ON ONE SECTION AND MOLE ON ONE SECTION BRANCH LINE : MOLE ON ONE SECTION, GOPHER ON ONE SECTION AND SQUIRREL ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs.	PW3 Rs	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	101	2643	D	3.01	3.01	3.01	10.67		10.67				150.53	68.522	60025	120050	800333	279237	279237	1079570
T1 - X1	2.37	330	2542	D	2.29	5.3	5.3	10.43		10.43				148.11	52.406	45908	91816	612107	220597	220597	832704
X1 - 206	0.87	454	2212	D	0.73	6.03	-3.38	10.35	1.04	11.39	245	122500	162925	118.02	12.215	10700	21400	142667	80979	80979	386571
206 - X2	1.25	685	1758	R	1.43	7.46	-1.95	11.23		11.23				95.14	22.369	19595	39190	261267	67899	67899	329166
X2 - X3	1.18	609	1073	G	1.53	8.99	-0.42	11.06		11.06				58.96	16.367	14337	28674	191160	43347	43347	234507
X3 - 254	1.38	464	464	M	1.86	10.85	1.44	10.85		10.85				25.99	9.035	7915	15830	105533	34637	34637	140170
TO-1																					
						5.30	5.3			10.43											
X1 - 226	1.25	330	330	M	1.2	6.5	6.5	10.3		10.3				19.47	4.593	4023	8046	53640	31374	31374	85014
TO-2																					
						7.46	-1.95			11.23											
X2 - 207	1.38	685	685	G	1.14	8.6	-0.81	11.1		11.1				37.5	7.743	6783	13566	90440	50694	50694	141134
TO-3																					
						8.99	-0.42			11.06											
X3 - 253	1.38	609	609	S	1.22	10.21	0.8	10.93		10.93				33.86	7.67	6719	13438	89587	46920	46920	136507
TOTAL													162925		200.92	176005	352010	2346734	855684	855684	3365343

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133988
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40691
SQUIRREL	S	1.616	0.00145	34400
MOLE	M	3.231	0.00250	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

DESIGN OF CONDUCTOR BASED ON 20TH YEAR DEMAND
PROJECT LIFE = 30 Years

YEAR	COST. Rs.			PRESENT WORTH OF COSTS Rs		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,233,182	0	1,712	1,072,332	1,489	1,073,821
2	0	0	3,261	0	2,466	2,466
3	0	0	6,212	0	4,084	4,084
4	0	0	11,834	0	6,766	6,766
5	0	0	22,544	0	11,208	11,208
6	0	0	25,762	0	11,138	11,138
7	0	0	29,439	0	11,067	11,067
8	0	0	33,641	0	10,997	10,997
9	0	0	38,443	0	10,928	10,928
10	0	0	43,930	0	10,859	10,859
11	0	0	49,362	0	10,610	10,610
12	0	0	55,465	0	10,367	10,367
13	0	0	62,323	0	10,129	10,129
14	0	0	70,029	0	9,897	9,897
15	0	0	78,688	0	9,670	9,670
16	0	0	87,183	0	9,317	9,317
17	0	0	96,595	0	8,976	8,976
18	0	0	107,023	0	8,648	8,648
19	0	0	118,577	0	8,332	8,332
20	0	0	131,380	0	8,027	8,027
21	0	0	136,056	0	7,229	7,229
22	0	0	140,898	0	6,510	6,510
23	0	0	145,913	0	5,862	5,862
24	0	0	151,106	0	5,279	5,279
25	0	0	156,484	0	4,754	4,754
26	0	0	161,526	0	4,267	4,267
27	0	0	166,731	0	3,830	3,830
28	0	0	172,103	0	3,438	3,438
29	0	0	177,648	0	3,085	3,085
30	0	0	183,372	0	2,769	2,769
SALVAGE VALUE	616,591	0	0	9,312	0	9,312
			TOTAL NPV	1,081,645	221,998	1,303,642

TABLE T2-26A

VOLTAGE DROP STUDIES BASED ON 1ST YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE H : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION. (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs	CURRENT Amps	LOSSES kW (3LI²R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs.	LINE COST Rs.	PW3 Rs	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	10	263	P	0.17	0.17	0.17	10.98		10.98				14.56	0.321	281	562	3747	399264	399264	403011
T1 - X1	2.37	33	253	P	0.13	0.3	0.3	10.97		10.97				14.02	0.235	206	412	2747	315419	315419	318166
X1 - 206	0.87	45	220	P	0.04	0.34	0.34	10.97		10.97				12.19	0.065	57	114	760	115787	115787	116547
206 - X2	1.25	68	175	D	0.08	0.42	0.42	10.96		10.96				9.7	0.119	104	208	1387	116349	116349	117736
X2 - X3	1.18	61	107	R	0.08	0.5	0.5	10.95		10.95				5.94	0.082	72	144	960	64856	64856	65856
X3 - 254	1.38	46	46	G	0.08	0.58	0.58	10.94		10.94				2.56	0.036	32	64	427	50694	50694	51121
TO-1																					
						0.30	0.3			10.97											
X1 - 226	1.25	33	33	G	0.05	0.35	0.35	10.96		10.96				1.83	0.017	15	30	200	45919	45919	46119
TO-2																					
						0.42	0.42			10.96											
X2 - 207	1.38	68	68	R	0.06	0.48	0.48	10.95		10.95				3.77	0.039	34	68	453	74960	74960	75413
TO-3																					
						0.50	0.5			10.95											
X3 - 253	1.38	61	61	G	0.1	0.6	0.6	10.94		10.94				3.39	0.063	55	110	733	50694	50694	51427
TOTAL													0		0.977	856	1712	11414	1233182	1233182	1244596

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591.
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-26B

VOLTAGE DROP STUDIES BASED ON 5TH YEAR DEMAND DISTRICT OKARA . TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE 1 : WITHOUT REGULATOR MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION. BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI²R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs.	LINE COST Rs.	PW3 Rs	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	36	947	P	0.63	0.63	0.63	10.93		10.93				52.65	4.191	3671	7342	49947	399264	399264	448211
T1 - X1	2.37	118	911	P	0.47	1.1	1.1	10.88		10.88				50.89	3.093	2709	5418	36120	315419	315419	351539
X1 - 206	0.87	163	793	P	0.15	1.25	1.25	10.86		10.86				44.38	0.864	757	1514	10093	115787	115787	125880
206 - X2	1.25	246	630	D	0.3	1.55	1.55	10.83		10.83				35.35	1.575	1380	2760	18400	116349	116349	134749
X2 - X3	1.18	218	384	R	0.29	1.84	1.84	10.8		10.8				21.61	1.089	954	1908	12720	64096	64096	76816
X3 - 254	1.38	166	166	G	0.28	2.12	2.12	10.77		10.77				9.37	0.483	423	846	5640	50694	50694	56334
TO-1																					
						1.10	1.1			10.88											
X1 - 226	1.25	118	118	G	0.16	1.28	1.28	10.86		10.86				6.6	0.217	190	380	2533	45919	45919	48452
TO-2																					
						1.55	1.55			10.83											
X2 - 207	1.38	246	246	R	0.22	1.77	1.77	10.81		10.81				13.83	0.522	457	914	6093	74960	74960	81053
TO-3																					
						1.84	1.84			10.8											
X3 - 253	1.38	218	218	G	0.36	2.2	2.2	10.76		10.76				12.31	0.834	731	1462	9747	50694	50694	60441
TOTAL													0		12.868	11272	22544	150293	1233182	1233182	1383475

CONDUCTOR	ABBR	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	48591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

FLOPPY NO 999A 1168F110 MK1

TABLE T2-26C

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA . GRID STATION GS-8 .
11 kV MAIN FEEDER F1 . 1-OFF 1,2,3
CASE 0 : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION. BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION. (INCLUDING O & M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PV1 Rs.	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PV2 Rs.	LINE COST Rs.	PV3 Rs.	TOTAL PVC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	59	1315	P	0.87	0.87	0.87	10.9		10.9				73.32	8.129	7120	14240	94933	399264	531021	625954
T1 - X1	2.37	164	1265	P	0.66	1.53	1.53	10.83		10.83				70.98	6.018	5272	10544	70293	315419	419507	489800
X1 - 206	0.87	226	1101	P	0.21	1.74	1.74	10.81		10.81				61.9	1.68	1472	2944	15627	115787	153997	173624
206 - X2	1.25	341	875	D	0.42	2.16	2.16	10.76		10.76				49.42	3.077	2695	5390	35933	116349	154744	190677
X2 - X3	1.18	302	534	R	0.41	2.57	2.57	10.72		10.72				30.27	2.138	1873	3746	24973	64096	85248	110221
X3 - 254	1.38	231	231	G	0.39	2.96	2.96	10.68		10.68				13.14	0.951	833	1666	11107	50694	67423	78530
TO-1																					
						1.53	1.53			10.83											
X1 - 226	1.25	164	164	G	0.25	1.78	1.78	10.8		10.8				9.23	0.425	372	744	4960	45919	61072	66832
TO-2																					
						2.16	2.16			10.76											
X2 - 207	1.38	341	341	R	0.31	2.47	2.47	10.73		10.73				19.31	1.017	891	1782	11880	74960	99697	111577
TO-3																					
						2.57	2.57			10.72											
X3 - 253	1.38	303	303	G	0.51	3.08	3.08	10.67		10.67				17.26	1.64	1437	2874	19160	50694	67423	96583
TOTAL													0		25.074	21965	43930	292866	1233182	1640132	1932998

CONDUCTOR	ACSR	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PV1 = Present Worth of Cost of Voltage Regulator
PV2 = Present Worth of Cost of Losses
PV3 = Present Worth of Line Cost
PVC = Present Worth of Total Cost (PV1+PV2+PV3)

FLOPPY NO 9994 11SEP11E VK1

TABLE T2-26C1

VOLTAGE DROP STUDIES BASED ON 10TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE J : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION. BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION. (EXCLUDING 4M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs.	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PW2 Rs.	LINE COST Rs.	PW3 Rs.	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	50	1315	P	0.87	0.87	0.87	10.9		10.9				73.32	8.126	7120	14240	94933	399264	399264	494197
T1 - X1	2.37	164	1265	P	0.65	[illegible]	1.53	10.83		10.83				70.98	6.018	5272	10544	70293	315419	315419	385712
X1 - 206	0.87	226	1101	P	0.21	1.74	1.74	10.81		10.81				61.9	1.68	1472	2944	19627	115787	115787	135414
206 - X2	1.25	341	875	D	0.42	2.16	2.16	10.76		10.76				49.42	3.077	2695	5390	35933	116349	116349	152282
X2 - X3	1.18	303	534	R	0.41	2.57	2.57	10.72		10.72				30.27	2.138	1873	3746	24973	64096	64096	89069
X3 - 254	1.38	231	231	G	0.39	2.96	2.96	10.68		10.68				13.14	0.951	833	1666	11107	50694	50694	61801
T1-1																					
						1.53	1.53			10.83											
X1 - 226	1.25	164	164	G	0.25	1.78	1.78	10.8		10.8				9.23	0.425	372	744	4960	45919	45919	50879
T0-2																					
						2.16	2.16			10.76											
X2 - 207	1.38	341	341	R	0.31	2.47	2.47	10.73		10.73				19.31	1.017	891	1782	11880	74960	74960	86840
T0-3																					
						2.57	2.57			10.72											
X3 - 253	1.38	303	303	G	0.51	3.08	3.08	10.67		10.67				17.26	1.64	1437	2874	19160	50694	50694	69854
TOTAL													0		25.074	21965	43930	292866	1233182	1233182	1526048

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VDI PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

FLOPPY NO 9994 1168F111 WK1

TABLE T2-26D

VOLTAGE DROP STUDIES BASED ON 15TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 T-OFF 1,2,3
CASE K : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION.(EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs.	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs.	PW2 Rs.	LINE COST Rs.	PW3 Rs	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	67	1750	P	1.16	1.16	1.16	10.87		10.87				97.84	14.474	12679	25358	169053	399264	399264	568317
T1 - X1	2.37	218	1683	P	0.88	2.04	2.04	10.77		10.77				94.97	10.773	9437	18874	125827	315419	315419	441246
X1 - 206	0.87	301	1465	P	0.28	2.32	2.32	10.74		10.74				82.9	3.013	2639	5278	35187	115787	115787	150974
206 - X2	1.25	454	1164	D	0.55	2.87	2.87	10.68		10.68				66.23	5.527	4842	9684	64560	116349	116349	180909
X2 - X3	1.18	403	710	R	0.54	3.41	3.41	10.62		10.62				40.63	3.851	3373	6746	44973	64896	64896	109869
X3 - 254	1.38	307	307	G	0.51	3.92	3.92	10.57		10.57				17.65	1.715	1502	3004	20027	50694	50694	70721
TO-1																					
X1 - 226	1.25	218	218	G	0.33	2.04 2.37	2.04 2.37	10.73		10.77 10.73				12.35	0.761	667	1334	8893	45919	45919	54812
TO-2																					
X2 - 207	1.38	454	454	R	0.41	2.87 3.28	2.87 3.28	10.64		10.68 10.64				25.93	1.834	1607	3214	21427	74560	74560	96387
TO-3																					
X3 - 253	1.38	403	403	G	0.67	3.41 4.08	3.41 4.08	10.55		10.62 10.55				23.21	2.966	2598	5196	34640	50694	50694	85334
TOTAL													0		44.914	39344	78688	524587	1233182	1233182	1757769

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-26E

VOLTAGE DROP STUDIES BASED ON 20TH YEAR DEMAND. DISTRICT OKARA . TEHSIL OKARA GRID STATION GS-8
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE L : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs.	PW3 Rs.	TOTAL PWC Rs.
MAIN																					
0								11.00		11.00											
0 - T1	3	66	2248	P	1.48	1.48	1.48	10.84		10.84				125.03	24.016	21038	42076	200507	399264	399264	679771
T1 - X1	2.37	280	2162	P	1.13	2.61	2.61	10.72		10.72				122.56	17.942	15717	31434	209560	315419	315419	524979
X1 - 206	0.87	386	1882	P	0.36	2.97	2.97	10.68		10.68				107.09	5.029	4405	8810	58733	115787	115787	174520
206 - X2	1.25	583	1496	D	0.71	3.68	3.68	10.6		10.6				85.77	9.269	8120	16240	108267	116349	116349	224616
X2 - X3	1.18	518	913	R	0.7	4.38	4.38	10.53		10.53				52.69	6.477	5674	11348	75653	64896	64896	139749
X3 - 254	1.38	395	395	G	0.66	5.04	5.04	10.46		10.46				22.95	2.9	2540	5080	33867	50694	50694	84561
TO-1																					
						2.61	2.61			10.72											
X1 - 226	1.25	280	280	G	0.42	3.03	3.03	10.67		10.67				15.95	1.269	1112	2224	14827	45919	45919	60746
TO-2																					
						3.68	3.68			10.6											
X2 - 207	1.38	583	583	R	0.52	4.2	4.2	10.54		10.54				33.61	3.082	2700	5400	36000	74960	74960	110960
TO-3																					
						4.38	4.38			10.53											
X3 - 253	1.38	518	518	G	0.86	5.24	5.24	10.44		10.44				30.15	5.005	4384	8768	58453	50694	50694	109147
TOTAL													0		74.589	65630	131300	875867	1233182	1233182	2109049

CONDUCTOR	ABBR.	RESISTANCE PER kM	11kV VD% PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133888
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs. 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-26F

VOLTAGE DROP STUDIES BASED ON 25TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-6
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE M : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION. (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	93	2446	P	1.61	1.61	1.61	10.82		10.82				137.39	28.536	24998	49996	333307	399264	399264	732571
T1 - X1	2.37	305	2353	P	1.23	2.84	2.84	10.69		10.69				133.77	21.375	18725	37450	249667	315419	315419	565086
X1 - 206	0.87	420	2048	P	0.39	3.23	3.23	10.65		10.65				116.66	5.988	5245	10490	69933	115787	115787	185720
206 - X2	1.25	634	1628	D	0.77	4	4	10.57		10.57				93.6	11.039	9670	19340	128933	116349	116349	245282
X2 - X3	1.18	564	994	R	0.76	4.76	4.76	10.49		10.49				57.59	7.737	6778	13556	90373	64096	64096	154469
X3 - 254	1.38	430	430	G	0.72	5.48	5.48	10.41		10.41				25.1	3.469	3039	6078	40520	50694	50694	91214
TO-1																					
X1 - 226	1.25	305	305	G	0.46	2.84	2.84			10.69											
						3.3	3.3	10.64		10.64				17.42	1.513	1325	2650	17667	45919	45919	63586
TO-2																					
X2 - 207	1.38	634	634	R	0.57	4.00	4			10.57											
						4.57	4.57	10.51		10.51				36.66	3.667	3212	6424	42827	74960	74960	117787
TO-3																					
X3 - 253	1.38	564	564	G	0.94	4.76	4.76			10.49											
						5.7	5.7	10.39		10.39				32.99	5.993	5250	10500	70000	50694	50694	120694
TOTAL													0		89.317	78242	157484	1043227	1233182	1233182	2276409

CONDUCTOR	ABBR	RESISTANCE PER kM	11kV VDI PER kM	11kV LINE COST PER kM (Rs.)
PANTHER	P	0.168	0.00022	133088
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25039

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs. 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-26G

VOLTAGE DROP STUDIES BASED ON 30TH YEAR DEMAND DISTRICT OKARA TEHSIL OKARA GRID STATION GS-0
11 kV MAIN FEEDER F1 . T-OFF 1,2,3
CASE N : WITHOUT REGULATOR. MAIN LINE :PANTHER ON THREE SECTIONS, DOG ON ONE SECTION, RABBIT ON ONE SECTION AND GOPHER ON ONE SECTION BRANCH LINE : GOPHER ON TWO SECTIONS AND RABBIT ON ONE SECTION. (EXCLUDING O&M)

PF = 0.95

SECTION	DISTANCE KM	SECTION LOAD kW	TOTAL LOAD kW	CONDUCTOR TYPE	SECTION VOLTAGE DROP %	TOTAL VOLTAGE DROP % BVR	TOTAL VOLTAGE DROP % AVR	VOLTAGE AT NODE kV BVR	VOLTAGE REGULATION kV	VOLTAGE AT NODE kV AVR	VOLTAGE REGULATOR SIZE KVA	VOLTAGE REGULATOR COST Rs	PW1 Rs	CURRENT Amps	LOSSES kW (3LI^2R)	LOSSES kWH	LOSSES COST Rs	PW2 Rs	LINE COST Rs	PW3 Rs	TOTAL PWC Rs
MAIN																					
0								11.00		11.00											
0 - T1	3	101	2643	P	1.74	1.74	1.74	10.81		10.81				148.58	33.379	29240	58480	399264	399264	399264	798131
T1 - X1	2.37	330	2542	P	1.33	3.07	3.07	10.67		10.67				144.78	25.038	21933	43866	292440	315419	315419	607859
X1 - 206	0.87	454	2212	P	0.42	3.49	3.49	10.63		10.63				126.46	7.012	6143	12286	81907	115787	115787	197694
206 - X2	1.25	685	1758	D	0.84	4.33	4.33	10.54		10.54				101.36	12.945	11340	22680	151200	116349	116349	267549
X2 - X3	1.18	609	1073	R	0.82	5.15	5.15	10.45		10.45				62.4	9.084	7958	15916	106107	64096	64096	170203
X3 - 254	1.38	464	464	G	0.77	5.92	5.92	10.37		10.37				27.19	4.071	3566	7132	47547	50634	50634	98241
TO-1																					
						3.07	3.07			10.67											
X1 - 226	1.25	330	330	G	0.5	3.57	3.57	10.62		10.62				18.88	1.778	1558	3115	20773	45919	45919	66692
TO-2																					
						4.33	4.33			10.54											
X2 - 207	1.38	685	685	R	0.61	4.94	4.94	10.48		10.48				39.72	4.384	3770	7540	50267	74960	74960	125227
TO-3																					
						5.15	5.15			10.45											
X3 - 253	1.38	609	609	G	1.02	6.17	6.17	10.34		10.34				35.79	7.053	6178	12356	82373	50634	50634	133067
TOTAL													0		104.664	91686	183372	1222481	1233182	1233182	2455663

CONDUCTOR	ABBR	RESISTANCE PER km	11kV VD% PER km	11kV LINE COST PER km (Rs)
PANTHER	P	0.168	0.00022	133888
DOG	D	0.336	0.00038	93079
RABBIT	R	0.659	0.00065	54319
GOPHER	G	1.330	0.00121	36735
WEASEL	W	1.100	0.00102	40591
SQUIRREL	S	1.616	0.00145	34000
MOLE	M	3.231	0.00290	25099

LOSS FACTOR HOURS = 876

VOLTAGE REGULATOR COST PER kVA = Rs 500

COST OF LOSSES PER kWH = Rs 2.00

AVR = After Voltage Regulation
BVR = Before Voltage Regulation
PW1 = Present Worth of Cost of Voltage Regulator
PW2 = Present Worth of Cost of Losses
PW3 = Present Worth of Line Cost
PWC = Present Worth of Total Cost (PW1+PW2+PW3)

TABLE T2-27

EVALUATION OF NET PRESENT WORTH OF COST OF 11 kV DISTRIBUTION LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 10TH YEAR DEMAND.
PROJECT LIFE = 15 Years

YEAR	COST Rs			PRESENT WORTH OF COSTS. Rs.		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	855,684	0	3,386	744,073	2,944	747,017
2	0	0	6,473	0	4,895	4,895
3	0	0	12,374	0	8,136	8,136
4	0	0	23,655	0	13,525	13,525
5	0	0	45,222	0	22,483	22,483
6	0	0	51,196	0	22,133	22,133
7	0	0	57,959	0	21,789	21,789
8	0	0	65,615	0	21,450	21,450
9	0	0	74,283	0	21,116	21,116
10	0	0	84,096	0	20,787	20,787
11	0	0	95,636	0	20,556	20,556
12	0	0	108,760	0	20,328	20,328
13	0	0	123,685	0	20,102	20,102
14	0	0	140,658	0	19,879	19,879
15	0	0	159,962	0	19,658	19,658
SALVAGE VALUE	427,842	0	0	52,579	0	52,579
			TOTAL NPV	796,652	259,782	1,056,435

TABLE T2-28

EVALUATION OF NET PRESENT WORTH OF COST OF 11 kV DISTRIBUTION LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 20TH YEAR DEMAND
PROJECT LIFE = 15 Years

YEAR	COST Rs			PRESENT WORTH OF COSTS Rs		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,233,182	0	1,712	1,072,332	1,489	1,073,821
2	0	0	3,261	0	2,466	2,466
3	0	0	6,212	0	4,084	4,084
4	0	0	11,834	0	6,766	6,766
5	0	0	22,544	0	11,208	11,208
6	0	0	25,762	0	11,138	11,138
7	0	0	29,439	0	11,067	11,067
8	0	0	33,641	0	10,997	10,997
9	0	0	38,443	0	10,928	10,928
10	0	0	43,930	0	10,859	10,859
11	0	0	49,362	0	10,610	10,610
12	0	0	55,465	0	10,367	10,367
13	0	0	62,323	0	10,129	10,129
14	0	0	70,029	0	9,897	9,897
15	0	0	78,688	0	9,670	9,670
SALVAGE VALUE	616,591	0	0	75,776	0	75,776
			TOTAL NPV	1,148,108	131,676	1,279,784

AT TABT2-28.WK1

TABLE T2-29

EVALUATION OF NET PRESENT WORTH OF COST OF 33 kV DISTRIBUTION LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 10TH YEAR DEMAND
PROJECT LIFE = 30 Years

YEAR	COST Rs.			PRESENT WORTH OF COSTS. Rs.		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,026,621	0	376	892,888	327	893,215
2	0	0	719	0	544	544
3	0	0	1,375	0	904	904
4	0	0	2,629	0	1,503	1,503
5	0	0	5,024	0	2,498	2,498
6	0	0	5,688	0	2,459	2,459
7	0	0	6,440	0	2,421	2,421
8	0	0	7,291	0	2,383	2,383
9	0	0	8,254	0	2,346	2,346
10	0	0	9,344	0	2,310	2,310
11	0	0	10,626	0	2,284	2,284
12	0	0	12,084	0	2,259	2,259
13	0	0	13,742	0	2,233	2,233
14	0	0	15,628	0	2,209	2,209
15	0	0	17,774	0	2,184	2,184
16	0	0	19,445	0	2,078	2,078
17	0	0	21,273	0	1,977	1,977
18	0	0	23,273	0	1,881	1,881
19	0	0	25,461	0	1,789	1,789
20	0	0	27,857	0	1,702	1,702
21	0	0	28,868	0	1,534	1,534
22	0	0	29,916	0	1,382	1,382
23	0	0	31,002	0	1,245	1,245
24	0	0	32,127	0	1,122	1,122
25	0	0	33,294	0	1,011	1,011
26	0	0	34,384	0	908	908
27	0	0	35,510	0	816	816
28	0	0	36,672	0	732	732
29	0	0	37,872	0	658	658
30	0	0	39,112	0	591	591
SALVAGE VALUE	513,411	0	0	7,754	0	7,754
			TOTAL NPV	900,642	48,291	948,933

AT TABT2-29.WK1

TABLE T2-30

EVALUATION OF NET PRESENT WORTH OF COST OF 33 kV DISTRIBUTION
LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 20TH YEAR DEMAND
PROJECT LIFE = 30 Years

YEAR	COST Rs			PRESENT WORTH OF COSTS Rs		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,479,010	0	190	1,286,798	165	1,286,963
2	0	0	362	0	274	274
3	0	0	690	0	454	454
4	0	0	1,315	0	752	752
5	0	0	2,505	0	1,245	1,245
6	0	0	2,860	0	1,238	1,238
7	0	0	3,272	0	1,230	1,230
8	0	0	3,739	0	1,222	1,222
9	0	0	4,273	0	1,215	1,215
10	0	0	4,881	0	1,207	1,207
11	0	0	5,485	0	1,179	1,179
12	0	0	6,163	0	1,152	1,152
13	0	0	6,925	0	1,126	1,126
14	0	0	7,781	0	1,100	1,100
15	0	0	8,743	0	1,074	1,074
16	0	0	9,687	0	1,035	1,035
17	0	0	10,733	0	997	997
18	0	0	11,892	0	961	961
19	0	0	13,176	0	926	926
20	0	0	14,598	0	892	892
21	0	0	15,117	0	803	803
22	0	0	15,655	0	723	723
23	0	0	16,212	0	651	651
24	0	0	16,789	0	587	587
25	0	0	17,387	0	528	528
26	0	0	17,947	0	474	474
27	0	0	18,525	0	426	426
28	0	0	19,122	0	382	382
29	0	0	19,738	0	343	343
30	0	0	20,374	0	308	308
SALVAGE VALUE	739,909	0	0	11,175	0	11,175
			TOTAL NPV	1,297,973	24,667	1,322,641

AT TABT2-30.WK1

TABLE T2-31

EVALUATION OF NET PRESENT WORTH OF COST OF 33 kV DISTRIBUTION LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA.
DESIGN OF CONDUCTOR BASED ON 10TH YEAR DEMAND.
PROJECT LIFE = 15 Years

YEAR	COST Rs.			PRESENT WORTH OF COSTS Rs.		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,026,621	0	376	892,888	327	893,215
2	0	0	719	0	544	544
3	0	0	1,375	0	904	904
4	0	0	2,629	0	1,503	1,503
5	0	0	5,024	0	2,498	2,498
6	0	0	5,688	0	2,459	2,459
7	0	0	6,440	0	2,421	2,421
8	0	0	7,291	0	2,383	2,383
9	0	0	8,254	0	2,346	2,346
10	0	0	9,344	0	2,310	2,310
11	0	0	10,626	0	2,284	2,284
12	0	0	12,084	0	2,259	2,259
13	0	0	13,742	0	2,233	2,233
14	0	0	15,628	0	2,209	2,209
15	0	0	17,774	0	2,184	2,184
SALVAGE VALUE	513,411	0	0	63,095	0	63,095
			TOTAL NPV	955,983	28,864	984,847

AT TABT2-31.WK1

TABLE T2-32

EVALUATION OF NET PRESENT WORTH OF COST OF 33 KV DISTRIBUTION
LINES OF FEEDER F1 GRIDSTATION GS-8, DISTRICT OKARA
DESIGN OF CONDUCTOR BASED ON 20TH YEAR DEMAND
PROJECT LIFE = 15 Years

YEAR	COST Rs			PRESENT WORTH OF COSTS Rs		
	CAPITAL	VOLATGE REGULATOR	LOSSES	CAPITAL + REGULATOR	LOSSES	TOTAL
1	1,479,818	0	190	1,286,798	165	1,286,963
2	0	0	362	0	274	274
3	0	0	690	0	454	454
4	0	0	1,315	0	752	752
5	0	0	2,505	0	1,245	1,245
6	0	0	2,863	0	1,238	1,238
7	0	0	3,272	0	1,230	1,230
8	0	0	3,739	0	1,222	1,222
9	0	0	4,273	0	1,215	1,215
10	0	0	4,881	0	1,207	1,207
11	0	0	5,485	0	1,179	1,179
12	0	0	6,163	0	1,152	1,152
13	0	0	6,925	0	1,126	1,126
14	0	0	7,781	0	1,100	1,100
15	0	0	8,743	0	1,074	1,074
SALVAGE VALUE	739,909	0	0	90,931	0	90,931
			TOTAL NPV	1,377,729	14,632	1,392,361

AT TABT2-32.WK1

ANNEX T3
DESIGN STUDIES OF DISTRIBUTION TRANSFORMERS

ANNEX T3

DESIGN STUDIES OF DISTRIBUTION TRANSFORMERS

1 SCOPE

A number of studies were carried out to examine the influence of review of the present WAPDA transformer standards on overall costs. These studies also included design of low cost three phase and single phase transformers of capacity 5 kVA, 10 kVA, 15 kVA & 20 kVA with slightly higher losses.

2 OPTIONS

Present WAPDA Standards

The bills of quantities and cost estimates of the present WAPDA Standard three phase, transformers (25 kVA to 630 kVA) are given in Table T3-1.

Low Cost Transformers

The bills of quantities and cost estimates of low cost, three phase transformers of sizes 5 kVA to 630 kVA are given in Table T3-2.

The bills of quantities and cost estimates of low cost single phase transformers of sizes 5 kVA to 50 kVA are given in Table T3-3.

3 DIFFERENT DESIGNS

A number of different designs of three phase transformers of sizes 5 kVA to 75 kVA were studied and cost comparisons made. The bills of quantities and cost comparisons are given in Tables T3-4 and T3-5.

Detailed analysis of factors affecting transformer design and costs is presented separatelty in this Annex.

4 CONCLUSIONS

Transformer losses have a significant impact on transformer costs. Single phase transformers are subsantially cheaper than three phase transformers. Slightly higher loss transformers should be evaluated to determine optimum loss level with reference to the economic cost of electricty supply.

ANNEX T3
TRANSFORMER DESIGN

At present the Pakistani manufacturers are manufacturing 11/0.415 kV pole mounted distribution transformers upto 200 kVA for installation in rural areas. Platform mounted transformers of sizes 400 and 630 kVA are also being manufactured locally

The existing WAPDA transformers for rural electrification have the following characteristics.

Ratings 25, 50, 100 and 200 kVA
Voltage ratio : 11/415 kV
Tappings : 2.5 - 5 - 7.5
Connection vector group DY11

Iron/copper losses :	Iron loss W	Copper loss W
- 25 kVA	123	640
- 50 "	175	1,170
- 100 "	310	2,020
- 200 "	495	3,410

Impedance 4%
Regulation at rated load and unity power factor

- 25 kVA	:	2.6 %
- 50 "	:	2.4 %
- 100 "	:	2.1 %
- 200 "	:	1.8 %

Tap changers

The existing WAPDA standards specify a tap changer with 5 tap positions. In practice the tap changer is seldom used. In fact, the tap changer is some time a source of failure because of the loose contacts. It may be a better solution to have transformers with voltage ratio 11/0.420 instead of 11/0.415 which is equivalent to about 5% fixed voltage regulation and savings in the cost of tap changer. The Karachi Electric Supply Company have already introduced this voltage ratio (i.e. 11/0.420 kV) in their system.

Temperature Rise

In the old days, the temperature rise allowed for 50 C degree ambient temperature was 40 C degree for oil and 50 C degree for windings. With the advancements in materials technology, the international standards (IEC-76, BSS-171, VDE-0532, ASA - C 57.12) have allowed, for ambients of 50 C degree, a temperature rise of 50 C degree in oil and 55 C degree in winding.

Taking into account the difference in ambient temperature (10 C degree) an increase of 5 C degree in winding temperature will bring the WAPDA Standard at par with the international standards. This increase in the allowable temperature rise will result in about 5-6 % reduction in the cost of transformers.

Vector Group

In Europe, up to 500 kVA, Vector Group is either YzS or YyO. In America, T-T connections for distribution 3 phase transformers are in vogue.

In star connected primaries, the advantage goes to the manufacturers

Total number of turns per phase is reduced to 0 577 times the delta connected windings.
Copper X-section is increased to 1.732 times the delta connected windings.

Using these connections it is possible to go into small sizes say up to 5 kVA, 3 phase. With delta winding the X-section becomes so small that it becomes very difficult to manufacture windings. Further, the production is reduced and as a result the price is increased.

The advantage of Delta Connected winding is that, due to closed circuit, it reduces the effect of harmonics, particularly the 3rd harmonic. Since the distribution transformers are manufactured at a very low flux density. They do not produce appreciable harmonics in the circuit. Hence, without any fear star/star or star/zigzag winding connections can be used.

Efficiency at full load = (output) / (output + losses) x100

- 25 kVA : 97.04 %
- 50 " : 97.38 %
- 100 " : 97.72 %
- 200 " : 98.08 %

Type of cooling : ON AN (Oil Natural, Air Natural)
Type of tank : Sealed
Ambient temperature : 50 C
Temperature rise

- Oil 40 C
- Winding 50 C

Bird protection : Epoxy raisin coating on top cover

Factors affecting cost of transformers

Major items which affect the cost of transformers are (1) copper winding, (2) silicon sheet, (3) insulation material, (4) transformer oil, (5) mild steel sheet, (6) elliptical tubes for cooling, (7) HT. and LT. bushings, (8) tap changer and (9) miscellaneous material, painting etc. Of the total manufacturing cost, the material alone accounts for about 71% of the total cost. The remaining 29% of the cost covers (1) labour, (2) overheads and (3) profits of the manufacturers. Generally, the labour, overheads and profit vary between 25% (for transformers of size 200 - 630 kVA) and 40% (for transformers of size 5 - 100 kVA) of the cost of material.

The distribution of cost of material for a typical 25 kVA 3-phase distribution transformer currently being used by WAPDA is as follows:

Copper windings including insulation	43.1 %
Silicon sheet	26.2 %
Transformer oil	10.5 %
Bushings and tap changer	10.7 %
Steel sheet including elliptical tube	6.1 %
Miscellaneous	3.4 %
	100.0 %

Copper weight

The copper weight in the transformer is inversely proportional to the allowable copper losses. As an example, for a 25 kVA transformer, the copper weight variation with the losses is as under:

	Copper Losses		Copper Weight	
	W	%	Kg	%
Design 1 (Standard WAPDA)	640	100.0	47	100
Design 2	841	131.4	26.5	56.4
Design 3	853	133.3	27.0	57.4

As may be seen about 33% increase in copper losses can result in about 42.6% reduction in the copper weight. Keeping in view the high cost of peak power in the WAPDA system and the load factor of the customers in the rural system, the optimal design of the transformer should be determined by comparing the present worth of cost savings in cheaper transformers and the extra cost of losses.

As an example, the case of a 25 kVA standard WAPDA transformer can be examined. The capital cost of a standard transformer is estimated at about 14,884 rupees, to maintain 640 W copper losses. In case, the copper losses are increased by 226 W, the cost of transformer can be reduced to about 11,554 rupees. The cost saving in capital investment per transformer can be about 3335 rupees or about 22.4%. The additional copper losses at an annual load factor of about 25% result in about 495 kWh energy losses per year. At the same time, the installed capacity of the generation and transmission system will also be increased by about 145 W and 190 W respectively. In economic terms, the economic cost - benefit analysis is not in favour of the cheaper transformers, as given below:

Savings

Capital investment in transformer = 3,330 Rs.

Additional capital cost

Capital investment in generation & transmission 0.190 x 30,000 = 5,700 Rs

Additional operating cost

Energy losses 495 x 0.61 = 300 Rs

PWC = 3,000 Rs

Net losses

Present worth of Net Benefits : 3330-5700-3000 =-5370

Based on the above evaluation methodology, the case for cheaper transformers with higher copper losses cannot be made. However, if the evaluation methodology takes into account the introduction of load management in rural areas (especially for certain categories of load such as tubewells), the case for cheaper transformers for all customers, who can accept dis-connection during peak hours, becomes quite different. In fact, in many cases, the cheaper transformers can make good economic sense. The entire evaluation methodology for comparing different levels of losses and corresponding cost savings needs to be examined very carefully. An alternative evaluation can be as follows:

Savings

Rs. 3330 Capital Savings

PWB = 3,330 Rs.

Additional cost

Generation & transmission capacity (Load management implemented) = 0

Energy losses 495 kWh @ 0.61 (off-peak energy) = 300 Rs.

PWC = 3000 Rs

Net-benefit

Present worth NPWB = 300 Rs

The above analysis shows that in rural systems where it is possible to disconnect the loads during peak hours, it can be economic to install cheaper transformers. This conclusion may be reinforced by past experience which shows that there is a high transformer failure in the WAPDA systems and the theoretical life of the transformer, which is basic to loss evaluation, is never achieved in real life. With a life of only 10 years as opposed to 30 years, the PWC of losses reduces to only 1840 RS

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Silicon sheet

Silicon sheet weight is related to the number of turns of HT and LT windings. Generally, when the copper weight increases (i.e. more turns), the silicon sheet weight is decreased. The price of silicon sheet and copper is nearly equal for an economical design of transformer

Transformer oil and mild steel tubes

With increased losses, an increase in surface area is required. For low loss transformers, the requirement of transformer oil and mild steel tubes for cooling is reduced.

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ANNEX - T3
DESIGN STUDIES OF DISTRIBUTION TRANSFORMERS
LIST OF TABLES

Table T3-1 : Standard three phase transformers. Bill of quantities and estimates of cost

2 : Low cost three phase transformers. Bill of quantities and estimates of cost

3 : Low cost single phase transformers. Bill of quantities and estimates of cost

4 : Comparison of different designs of three phase transformers of sizes 5-15 kVA

5 : Comparison of different designs of three phase transformers of sizes 25-75 kVA

TABLE T3-1

STANDARD THREE PHASE TRANSFORMERS BILL OF QUANTITIES AND ESTIMATES OF COST

NO.	DESCRIPTION	UNIT	UNIT RATE Rs.	BILL OF QUANTITIES/COST					
				25 kVA	50 kVA	100 kVA	200 kVA	400 kVA	630 kVA
A	BILL OF QUANTITIES								
1.	Copper weight	Kg	100	47	58	82	130	220	330
2.	Silicone sheet	Kg	40	69	110	170	300	505	725
3.	Insulation material	%		5.0	5.0	5.0	5.0	5.0	5.0
4.	Transformer oil	Gallon	75	16	25	42	65	110	145
5.	Mild steel sheet	Kg	11	40	61	96	146	246	409
6.	Elliptical tube	M	12.75	20	30	48	73	123	204
7.	11 kV bushing	No	175	3	3	3	3	3	3
8.	LV bushing	No.	50	4	4	4	4	4	4
9.	Tap changer	No.	200	1	1	1	1	1	1
10.	Miscellaneous		200,400	1	1	1	1	1	1
11.	Total weight	Kg		280	425	670	1020	1900	2860
12.	Copper losses	W		640	1170	2020	3410	5600	8150
13.	Iron losses	W		123	175	310	495	925	1350
B	MATERIAL COST (Rs.)								
1.	Copper			4700	5800	8200	13000	22000	33000
2.	Silicone sheet			2760	4400	6800	12000	20200	29000
3.	Insulation			235	290	410	650	1100	1650
4.	Transformer oil			1200	1875	3150	4875	8250	10875
5.	Steel sheet			440	671	1056	1606	2706	4499
6.	Elliptical tube			255	383	612	931	1568	2601
7.	11 kV bushing			525	525	525	525	525	525
8.	LV bushing			200	200	200	200	200	200
9.	Tap changer			200	200	200	200	200	200
10.	Miscellaneous			200	200	200	400	400	400
	Total material			10715	14544	21353	34387	57149	82950
	Labour and overheads			4286	5818	8541	8537	14287	20738
	Total cost			15001	20362	29894	42934	71436	103688

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TABLE T3-2

LOW COST THREE PHASE TRANSFORMERS BILL OF QUANTITIES AND ESTIMATES OF COST

NO	DESCRIPTION	UNIT	UNIT RATE Rs	BILL OF QUANTITIES / COST									
				5 kVA	10 kVA	15 kVA	20 kVA	25 kVA	50 kVA	100 kVA	200 kVA	400 kVA	630 kVA
A	BILL OF QUANTITIES												
1	Copper weight	kg	100	11	13	18	23	26	36	61	103	173	243
2	Silicone sheet	kg	40	22	27	43	58	65	123	207	348	585	822
3	Insulation material	%		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
4	Transformer oil	Gallon	75	7.2	8.5	10.0	10.4	15.1	22.1	37.0	62.0	104.0	146.0
5	Mild steel sheet	kg	11	29.5	32.0	34.0	38.3	41.1	52.8	89.0	150.0	252.0	354.0
6	Elliptical tube	M	12.75	0.46	0.58	0.60	0.48	13.20	37.80	64.00	108.00	182.00	256.00
7	11 kV bushing	No	175	3	3	3	3	3	3	3	3	3	3
8	LV bushing	No	50	4	4	4	4	4	4	4	4	4	4
9	Tap changer	No	200	1	1	1	1	1	1	1	1	1	1
10	Miscellaneous		200,400	1	1	1	1	1	1	1	1	1	1
11	Copper losses	W		189	408	571	719	866	1163	1956	3290	5533	7779
12	Iron losses	W		45	75	88	106	132	243	409	688	1157	1727
B	MATERIAL COST (Rs.)												
1	Copper			1100	1300	1800	2300	2600	3600	6100	10300	17300	24300
2	Silicone sheet			880	1480	1720	2320	2600	4920	8280	13920	23400	32880
3	Insulation			55	65	90	115	130	180	305	515	865	1215
4	Transformer oil			540	638	750	780	1133	1658	2775	4650	7800	10950
5	Steel sheet			325	352	374	421	452	581	979	1650	2772	3894
6	Elliptical tube			6	7	8	6	245	492	816	1377	2321	3264
7	11 kV bushing			525	525	525	525	525	525	525	525	525	525
8	LV bushing			200	200	200	200	200	200	200	200	200	200
9	Tap changer			200	200	200	200	200	200	200	200	200	200
10	Miscellaneous			200	200	200	200	200	200	200	400	400	400
	Total material			4031	4967	5867	7067	8295	12546	20380	33737	55783	77828
	Labour and overheads			1612	1987	2347	2827	3314	5018	8152	8434	13946	19457
	Total cost			5643	6954	8214	9894	11599	17564	28532	42171	69729	97285

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TABLE T3-3

LOW COST SINGLE PHASE TRANSFORMERS BILL OF QUANTITIES AND ESTIMATES OF COST

NO	DESCRIPTION	UNIT	UNIT RATE Rs	BILL OF QUANTITIES / COST					
				5 kVA	10 kVA	15 kVA	20 kVA	25 kVA	50 kVA
A	BILL OF QUANTITIES								
1.	Copper	Kg	100	6.5	11	15	13	22	36
2.	Silicone sheet	Kg	40	22	31	39	49	58	94
3.	Insulation material (of 1 above)	%	100	5	5	5	5	5	5
4	Transformer oil	Gallon	75	6	8	10	13	15	24
5.	Mild steel sheet	Kg	11	25	30	36	41	45	50
6.	Elliptical tube	M	12.75	0	0	10	20	30	50
7	11 kV bushing	No.	175	2	2	2	2	2	2
8.	LV bushing	No.	50	2	2	2	2	2	2
9.	Tap changer	No	200	1	1	1	1	1	1
10.	Copper losses	W		197	350	480	603	725	1170
11.	Iron losses	W		38	55	70	88	105	170
B.	COST (Rs.)								
1.	Copper	Rs.		650	1100	1500	1900	2200	3600
2.	Silicone sheet	Rs.		880	1240	1560	1960	2320	3760
3.	Insulation	Rs.		33	55	75	95	110	180
4.	Transformer oil	Rs.		450	600	750	975	1125	1800
5.	Mild steel sheet	Rs.		275	330	396	451	495	550
6.	Elliptical tube	Rs.		0	0	128	255	383	638
7.	11 kV bushing	Rs.		350	350	350	350	350	350
8.	LV bushing	Rs.		100	100	100	100	100	100
9.	Tap changer	Rs.		200	200	200	200	200	200
10.	Miscellaneous	Rs.		200	200	200	200	200	200
	Total material	Rs.		3138	4175	5259	6486	7483	11378
	Labour and overheads (@ 40% Of Material)	Rs.		1255	1670	2104	2594	2993	4551
	Total cost	Rs.		4393	5845	7363	9080	10476	15929

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TABLE T3-4

COMPARISON OF DIFFERENT DESIGNS OF THREE PHASE TRANSFORMERS OF SIZES 5 - 15 kVA

NO	DESCRIPTION	UNIT	UNIT RATE Rs	5 kVA Design-1	2	3	4	7.5 kVA 1	2	3	4	5	6	10 kVA 1	2	3	4	15 kVA 1	2	3	4	5
A	BILL OF QUANTITIES																					
1	Copper weight	kg	160	12.1	11.1	9.3	9.6	20.3	17.9	13	12	9.2	10.5	12.3	13.9	15.2	16.6	17.5	17.7	17.7	14.4	14.3
2	Silicon sheet	kg	40	21	22	26	26	27	27	30	32	33	32	37	35	40	40	41	44	43	49	39
3	Insulation material	kg of		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
4	Transformer oil	ltr	15	7.1	7.2	8.2	7.7	10.2	8.2	9	9	7.5	7.3	9.5	9.7	10.3	10.2	11.7	10	9.5	13.3	12.3
5	Mild steel sheet	kg	11	33.31	29.49	31.42	30.39	32.64	32.18	32.1	32.48	30.39	31.33	32.71	32.2	35.51	35.4	37.3	34.32	34.14	40.36	40.13
6	Elliptical tube	m	12.75	0.48	0.46	0.48	0.48	0.5	0.49	0.44	0.42	0.44	0.5	0.53	0.53	0.58	0.53	0.12	0.74	0.73	0.15	0.15
7	11 kV bushing	No	175	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
8	LV bushing	No	50	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
9	Tap changer	No	200	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	Copper losses	W		133	139	135	130	239	256	253	253	235	238	408	404	357	376	553	530	571	461	473
11	Iron losses	W		41	45	52	53	48	49	55	58	53	51	75	79	82	77	102	95	93	122	114
B	COST ESTIMATE																					
1	Copper	Rs		1210	1110	930	960	2030	1790	1300	1200	920	1050	1220	1390	1520	1660	1750	1770	1770	1440	1430
2	Silicon sheet	Rs		840	880	1040	1040	1080	1080	1200	1280	1320	1320	1480	1400	1600	1600	2040	1760	1720	2400	2000
3	Insulation material	Rs		41	36	50	48	104	90	65	60	46	53	45	70	75	75	93	99	93	72	74
4	Transformer oil	Rs		533	540	615	578	765	613	600	600	563	585	623	653	773	765	779	750	743	998	960
5	Mild steel sheet	Rs		319	324	346	334	359	354	353	357	341	341	352	354	391	389	417	378	376	441	442
6	Elliptical tube	Rs		3	3	3	3	3	3	3	3	3	3	3	3	3	3	4.5	3	3.4	3.93	3.20
7	11 kV bushing	Rs		525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525	525
8	LV bushing	Rs		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
9	Tap changer	Rs		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
10	Miscellaneous	Rs		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Total material		Rs		4093	4041	4172	4091	5519	5068	4649	4627	4321	4480	4957	5000	5492	5525	6338	5945	5897	6669	6561
Labour & overhead (@ 40% of Material)		Rs		1637	1616	1663	1636	2208	2027	1860	1851	1728	1792	1983	2000	2197	2210	2535	2378	2359	2668	2624
Total cost		Rs		5730	5657	5841	5727	7727	7095	6509	6478	6049	6272	6940	7000	7689	7735	8873	8323	8256	9337	9185
C	COST OF LOSSES																					
1	Copper Losses	Rs		845	829	854	832	1047	1121	1152	1108	1292	1261	1787	1770	1507	1647	2488	2497	2501	2019	2094
2	Iron Losses	Rs		713	753	811	823	841	858	864	1016	1034	1063	1314	1279	1437	1349	1787	1507	1542	2137	1997
Total cost				1563	1616	1765	1761	1888	1979	2116	2124	2326	2330	3101	3049	3044	2996	4275	4004	4043	4156	4091
D	PRESENT WORTH																					
1	Capital Cost (including 0 & M)	Rs		7521	7524	7763	7617	10277	9436	8657	8616	8045	8342	9220	9310	10226	10288	11891	11070	10990	12418	12216
2	Losses	Rs		10420	10773	11767	11740	12587	13193	14107	14160	15507	15533	20673	20327	20293	19973	25500	26633	26353	27707	27273
Total cost		Rs		18041	18297	19536	19357	22864	22629	22764	22776	23552	23875	29903	29637	30519	30261	40261	37753	37933	40125	39489

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TABLE T3-5

COMPARISON OF DIFFERENT DESIGNS OF THREE PHASE TRANSFORMERS OF SIZES 25 - 75 kVA

NO	DESCRIPTION	UNIT	UNIT RATE Rs.	25 kVA 1	25 kVA 2	25 kVA 3	25 kVA 4	37.5 kVA 1	37.5 kVA 2	37.5 kVA 3	37.5 kVA 4	75 kVA 1	75 kVA 2	75 kVA 3	75 kVA 4
A	BILL OF QUANTITIES														
1	Copper weight	kg	100	26.5	27	25.9	26	32.2	33.7	33	33.8	47.6	51.1	53.2	56
2	Silicon sheet	kg	40	65	65	65	67	91	88	87	85	166	148	141	1
3	Insulation material	(% of 1)		5	5	5	5	5	5	5	5	5	5	5	
4	Transformer oil	Gl	75	15.9	15.4	15.1	15.3	13.8	14	13.5	13.7	26.7	25.7	25.9	25.
5.	Mild steel sheet	kg	11	44.07	41.46	41.08	41.65	45.87	45.89	44.7	44.82	58.25	55.19	54.63	53.3
6.	Elliptical tube	M	12.75	19.34	19.47	19.17	18.87	32.8	34.3	33.6	34.4	55.18	58.42	60.04	61.6
7	11 kV bushing	No	175	3	3	3	3	3	3	3	3	3	3	3	
8.	LV bushing	No	50	4	4	4	4	4	4	4	4	4	4	4	
9.	Tap changer	No	200	1	1	1	1	1	1	1	1	1	1	1	
10.	Copper losses	W		841	853	866	841	997	1043	1085	1114	1559	1683	1752	178
11.	Iron losses	W		128	128	132	129	167	156	154	151	306	269	255	24
B.	COST ESTIMATE														
1.	Copper	Rs.		2650	2700	2590	2600	3220	3370	3300	3380	4760	5110	5320	561
2.	Silicon sheet	Rs.		2600	2600	2600	2680	3640	3520	3480	3400	6640	5920	5640	536
3.	Insulation material	Rs.		133	135	130	130	161	169	165	169	238	256	266	28
4.	Transformer oil	Rs.		1193	1155	1133	1148	1035	1050	1013	1028	2003	1928	1943	194
5.	Mild steel sheet	Rs.		485	456	452	458	505	505	492	493	641	607	602	59
6.	Elliptical tube	Rs		247	248	244	241	418	437	428	439	704	745	766	78
7.	11 kV bushing	Rs.		525	525	525	525	525	525	525	525	525	525	525	52
8.	LV bushing	Rs.		200	200	200	200	200	200	200	200	200	200	200	20
9.	Tap changer	Rs.		200	200	200	200	200	200	200	200	200	200	200	20
10.	Miscellaneous	Rs.		200	200	200	200	200	200	200	200	200	200	200	20
Total material		Rs.		8433	8419	8274	8382	10104	10176	10003	10034	16111	15691	15662	15699
Labour & overhead (@ 40% of Material)		Rs.		3373	3368	3310	3353	4042	4070	4001	4014	6444	6276	6265	6280
Total cost		Rs.		11806	11787	11584	11735	14146	14246	14004	14048	22555	21967	21927	21979
C.	COST OF LOSSES														
1	Copper Losses	Rs.		3684	3736	3793	3684	4367	4568	4752	4879	6828	7372	7674	7814
2	Iron Losses	Rs.		2243	2243	2313	2260	2926	2733	2698	2646	5361	4713	4468	4327
Total cost				5927	5979	6106	5944	7293	7301	7450	7525	12189	12085	12142	12141
D.	PRESENT WORTH														
1	Capital Cost (including O & M)	Rs.		15702	15677	15407	15608	18814	18947	18625	18684	29993	29216	29163	29232
2	Losses	Rs.		39513	39860	40707	39627	48620	48673	49667	50167	81260	80567	80947	80940
Total cost		Rs.		55215	55537	56114	55235	67434	67620	68292	68851	111258	109783	110110	110172

File name: Case3 (F/666) /STS/MIL

ANNEX T4
COST ESTIMATES OF DISTRIBUTION MATERIAL AND CONSTRUCTION

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ANNEX T4

COST ESTIMATES OF DISTRIBUTION MATERIAL AND CONSTRUCTION

1 SCOPE

Detailed analysis of cost estimates of distribution constructon are given for each conductor and transformer type in a separate report entitled "Detailed Analysis of cost of Distribution Construction". These estimate were prepared for the following three cases.

Case 1 : Standard WAPDA support but maximum allowable span with reference to pole strength and sag-tension calculations

2 : Low cost pretressed concrete poles only but maximum allowable spans with reference to pole strength and sag-tension calculations

3 : Standard WAPDA practice consisting of standard WAPDA structures and existing span lengths (440 ft for HT and 220 for LT).

The maximum allowable span lengths with reference to sag-tension and pole strength were determined as a part of a separate "Design Study of Distribution Pole Options", which is summarised in Annex T1.

The wooden poles (pole 1 and 2), which were included in the Design Study were excluded from the cost estimates.

2 POLE TYPES

The following 12 pole types were included in the cost estimates.

Case 1 : Standard WAPDA Supports. Maximum allowable Spans

Pole 3 : WAPDA Standard HT and Composite Line Steel Lattice Pole 34.66 ft height. 23 kg weight

4 : WAPDA Standard LT line steel lattice pole 31.17 ft height, 136 kg weight

5 : PTAT designed shortend WAPDA HT steel lattice pole 31.17 ft height, 150 kg weight

6 : WAPDA standard HT and composite line prestressed concrete pole. 36 ft height, 1079 kg weight

7 : WAPDA standard LT prestressed concrete pole. 31.17 ft. height, 696 kg weight

8 : PTAT designed shortened WAPDA HT prestressed concrete pole. 31.17 ft. height, 700 kg weight

Case 2 : Low Cost Supports. Maximum allowable Spans

Pole 9 : Low cost prestressed concrete pole 29.5 ft. height, 391 kg weight

10 : Low cost prestressed concrete pole 29.5 ft. height, 470 kg weight

11 : Low cost prestressed concrete pole 26.2 ft. height, 317 kg weight

12 : Low cost prestressed concrete pole. 26.2 ft. height, 364 kg weight

13 : Low cost prestressed concrete pole. 24.6 ft. height, 265 kg weight

14 : Low cost prestressed concrete pole. 24.6 ft. height, 310 kg weight

Case 3 : Standard WAPDA Practice. 440 ft. Span for HT and 220 ft. for LT

Pole 3 : WAPDA standard steel lattice pole for HT & composite lines

6 : WAPDA standard steel lattice pole for LT

3 COST ESTIMATES

The following distribution costs have been summarised in this Annex.

Three phase 11 kV line (Table T4-1)
Single phase 11 kV line (Table T4-2)
Three phase 0.4 kV line (Table T4-3)
Single Phase 0.23 kV line (Table T4-4)
Three phase composite line (Table 4-5)
11/0.4 kV three phase distribution transformers (Table T4-6)
33/0.4 kV three phase distribution transformers (Table T4-7)

ANNEX - T4

COST ESTIMATES OF DISTRIBUTION MATERIAL AND CONSTRUCTION

LIST OF TABLES

Table T4-1 : Cost of construction per km of three phase 11 kV line

2 : Cost of construction per km of single phase 11 kV line

3 : Cost of construction per km of three phase 0.4 kV line

4 : Cost of construction per km of single phase 0.23 kV line

5 : Cost of construction per km of three phase 11/0.4 kV composite line LT horizontal formation

6 : 11/0.4 kV three phase and single phase transformers

7 : 33/0.4 kV three phase and single phase transformers

TABLE 74-1

COST OF CONSTRUCTION PER KM OF THREE PHASE 11 KV LINE

Sr No	DESCRIPTION	COST Rs										
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13
1	MOLE CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	45127	42039	[illegible]891	32313	27958	27920					
	b. Case 2 Low Cost Supports							25099	-	29482	-	23059
	c. Case 3 Existing WAPDA Practice	55916			33394							
2.	SQUIRREL CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	51380	55976	51663	39657	35370	35692					
	b. Case 2 Low Cost Supports							36401	34000	35005	36473	38570
	c. Case 3 Existing WAPDA Practice	63663			47166							
3.	GOPHER CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	54116	58711	54338	42333	38465	38427					
	b. Case 2 Low Cost Supports							39137	36735	37741	39209	41305
	c. Case 3 Existing WAPDA Practice	66423			49301							
4.	WEASEL CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	57971	62567	58254	46248	42321	42283					
	b. Case 2 Low Cost Supports							42992	40591	41596	43064	45161
	c. Case 3 Existing WAPDA Practice	70279			53757							
5.	RABBIT CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	72368	85611	71979	60054	59272	59221					
	b. Case 2 Low Cost Supports							60280	54319	57224	58983	58039
	c. Case 3 Existing WAPDA Practice	83157			66635							
6.	DOG CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	111543	138385	109304	94476	101138	101128					
	b. Case 2 Low Cost Supports							102630	95802	93536	93073	96750
	c. Case 3 Existing WAPDA Practice	117571			101048							
7.	PANTHER CONDUCTOR											
	a. Case 1 Standard WAPDA Supports	162114	201347	154790	134736	147121	147018					
	b. Case 2 Low Cost Supports							149141	139117	143123	135130	140606
	c. Case 3 Existing WAPDA Practice	151376			134854							

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TABLE T4-1

COST OF CONSTRUCTION PER KM OF THREE PHASE 11 KV LINE

Sr No	DESCRIPTION	COST Rs											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
3	PELICAN CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	175175	214408	167851	147857	160183	160079						
	b. Case 2 Low Cost Supports							162202	152178	156185	148252	153667	146143
	c. Case 3 Existing WAPDA Practice	164438			147915								
3	OSPERY CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	205248	247634	197506	175953	189052	186372						
	b. Case 2 Low Cost Supports							181480	180642	184855	176347	182103	174038
	c. Case 3 Existing WAPDA Practice	190559			174036								

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TABLE T4-2

COST OF CONSTRUCTION PER KM OF SINGLE PHASE 11 KV LINE

Sr No	DESCRIPTION	COST Rs											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	PO 1
1	MOLE CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	40783	37649	39501	23475	22568	23531						
	b. Case 2 Low Cost Supports							20644	-	23759	-	24250	-
	c. Case 3 Existing WAPDA Practice	51417			34834								
2	SQUIRREL CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	44474	44433	46391	31210	29546	29505						
	b. Case 2 Low Cost Supports							26558	-	27764	-	29431	-
	c. Case 3 Existing WAPDA Practice	56536			40076								
3	GOPHER CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	44951	43175	44929	33763	29841	29804						
	b. Case 2 Low Cost Supports							26399	-	29587	-	32887	-
	c. Case 3 Existing WAPDA Practice	58421			41899								
4	WEASEL CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	48863	47224	49076	37145	33143	33105						
	b. Case 2 Low Cost Supports							30219	31348	32158	33626	35458	-
	c. Case 3 Existing WAPDA Practice	60392			44469								
5	RABBIT CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	58949	57147	58492	46635	42117	42076						
	b. Case 2 Low Cost Supports							39538	40742	43334	45098	44043	-
	c. Case 3 Existing WAPDA Practice	69577			53055								
6	DOG CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	81891	92028	84297	69577	67506	66348						
	b. Case 2 Low Cost Supports							62480	63898	63685	65153	66385	6682
	c. Case 3 Existing WAPDA Practice	92519			75997								
7	PANTHER CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	108681	124413	103756	90397	88065	87163						
	b. Case 2 Low Cost Supports							84283	82723	86803	90067	93313	8955
	c. Case 3 Existing WAPDA Practice	115056			99533								

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TABLE T4-2

COST OF CONSTRUCTION PER KM OF SINGLE PHASE 11 KV LINE

Sr No	DESCRIPTION	COST Rs											
		POLE 1	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
8	PELICAN CONDUCTOR												
	a Case 1 Standard WAPDA Supports	116908	142226	115541	100921	106408	97532						
	b Case 2 Low Cost Supports							94564	101140	97520	99284	101774	102354
	c Case 3 Existing WAPDA Practice	123764			107241								
9	OSPERY CONDUCTOR												
	a Case 1 Standard WAPDA Supports	136881	164103	132355	118226	125694	115007						
	b Case 2 Low Cost Supports							111973	113975	114935	117102	120585	119753
	c Case 3 Existing WAPDA Practice	141179			124656								

TABLE T4-3

COST OF CONSTRUCTION PER KM OF THREE PHASE 11 KV LINE

Sr No	DESCRIPTION	COST Rs											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
1.	GNAT CONDUCTOR												
	a. Case 1 Standard WAPDA Supports												
	- Vertical formation		67256	70563		43121	43052						
	- Horizontal formation		67133	56530		40323	40267						
	b. Case 2 Low Cost Supports												
	- Vertical formation							26348	33955	46034	50167	63801	78309
	- Horizontal formation							33293	36045	36375	36372	36771	38356
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		81500			49514							
2.	ANT CONDUCTOR												
	a. Case 1 Standard WAPDA Supports												
	- Vertical formation		86532	89915		62447	62378						
	- Horizontal formation		87220	77855		59026	58973						
	b. Case 2 Low Cost Supports												
	- Vertical formation							56274	58281	66669	71051	96109	106617
	- Horizontal formation							58063	55017	55740	57702	56899	59120
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		101226			68840							
3.	WASP CONDUCTOR												
	a. Case 1 Standard WAPDA Supports												
	- Vertical formation		140543	130731		104480	104405						
	- Horizontal formation		158117	121401		111920	111825						
	b. Case 2 Low Cost Supports												
	- Vertical formation							101937	100331	107496	111358	136925	147434
	- Horizontal formation							110229	104569	105137	101155	102946	101007
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		142042			103657							

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TABLE T4-3

COST OF CONSTRUCTION PER KM OF THREE PHASE 0.4 KV LINE

Sr No	DESCRIPTION	COST Rs.											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
4	CHAFER CONDUCTOR												
	a. Case 1 Standard WAPDA Supports												
	- Vertical formation		255745	226369		207105	207004						
	- Horizontal formation		273275	223907		217131	217004						
	b. Case 2 Low Cost Supports												
	- Vertical formation							203893	198926	203476	207926	234657	245587
	- Horizontal formation							214989	205876	208066	202578.	205091	200211
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		237680			205234							

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TABLE T4-4

COST OF CONSTRUCTION PER KM OF SINGLE PHASE 0.23 kV LINE

Sr No	DESCRIPTION	COST Rs.											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POL 1
1	SHAT CONDUCTOR												
	a Case 1 Standard WAPDA Supports												
	- Vertical formation		55145	58478		31010	30941						
	- Horizontal formation		44208	46590		26361	26311						
	b Case 2 Low Cost Supports												
	- Vertical formation							24763	26776	33114	37247	55002	641
	- Horizontal formation							22327	23718	23097	24861	24506	265
	c Case 3 Existing WAPDA Practice												
	- Vertical formation		69592			37196							
2	ANT CONDUCTOR												
	a Case 1 Standard WAPDA Supports												
	- Vertical formation		64908	68141		40673	40504						
	- Horizontal formation		54571	56253		36624	36574						
	b Case 2 Low Cost Supports												
	- Vertical formation							34432	36439	43999	48381	71138	816
	- Horizontal formation							33357	33381	33898	35860	34923	371
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		79245			46859							
3	WASP CONDUCTOR												
	a Case 1 Standard WAPDA Supports												
	- Vertical formation		85216	88549		61081	61012						
	- Horizontal formation		66121	76661		58788	58732						
	b Case 2 Low Cost Supports												
	- Vertical formation							56335	59535	64407	68790	81547	10205
	- Horizontal formation							57516	54403	55734	57342	56131	5956
	c. Case 3 Existing WAPDA Practice												
	- Vertical formation		89653			67268							

COMMODORE I-LT UNI

TABLE T4-4

COST OF CONSTRUCTION PER KM OF SINGLE PHASE 0.23 KV LINE

Sr No	DESCRIPTION	COST Rs.											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	POLE 14
4	CHAFER CONDUCTOR												
a	Case 1 Standard WAPDA Supports												
	- Vertical formation		135781	136369		108301	108831						
	- Horizontal formation		147142	113115		111472	111339						
b	Case 2 Low Cost Supports												
	- Vertical formation							104633	106415	112557	117007	141310	15224
	- Horizontal formation							103914	105700	105921	105762	104244	10633
c	Case 3 Existing WAPDA Practice												
	- Vertical formation		147473			115087							

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TABLE T4-5

COST OF CONSTRUCTION PER kM OF THREE PHASE 11/0.4 kV COMPOSITE LINE
LT HORIZONTAL FORMATION

Sr No.	DESCRIPTION	COST Rs.											
		POLE 3	POLE 4	POLE 5	POLE 6	POLE 7	POLE 8	POLE 9	POLE 10	POLE 11	POLE 12	POLE 13	PO 1
1	GNAT & SQUIRRE CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	95754	127280	102545	76793	80772	87118						
	b. Case 2 Low Cost Supports							84623	74163	84470	87998	139456	147
2	ANT & GOPHER CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	114540	150896	124606	96522	103530	103442						
	b. Case 2 Low Cost Supports							107606	96908	110871	114781	161513	163
3	WASP & RABBIT CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	203019	263466	192626	163679	184837	184753						
	b. Case 2 Low Cost Supports							191723	173315	182713	172331	219070	2273
4.	CHAFER & DOG CONDUCTOR												
	a. Case 1 Standard WAPDA Supports	362424	445459	348045	308427	337538	337340						
	b. Case 2 Low Cost Supports							346969	322810	334257	314679	349121	3574

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TABLE T4-6

11/0.4 kV THREE PHASE AND SINGLE PHASE TRANSFORMERS

NO	DESCRIPTION	COST Rs								
		5 kVA	10	15	20	25	50	100	200	400
A	TRANSFORMER COST Rs									
	1 Case 1 Standrad WAPDA 3-Phase					15001	20362	29894	42994	71436
	2 Case 2 Low Cost 3-Phase	5643	6954	8214	9894	11599	17564	28532	42171	69723
	3. Case 3 Low Cost 1-Phase	4393	5845	7363	9080	10476	15929			
B	SUBSTATION COST Rs									
	1. Case 1. Standrad WAPDA 3-Phase					4025	4025	7525	7525	7525
	2. Case 2. Low Cost 3-Phase	2500	2500	2500	2500	2500	2500	5692	5692	5692
	3 Case 3 Low Cost 1-Phase	2100	2100	2100	2100	2100	2100	4100	4100	4100
C.	TRANSFORMER & SUBSTATION COST Rs									
	1. Case 1 Standrad WAPDA 3-Phase					19026	24387	37419	50509	78961
	2. Case 2 Low Cost 3-Phase	8143	9454	10714	12394	14099	20064	34224	47863	75421
	3. Case 3 Low Cost 1-Phase	6493	7945	9463	11180	12576	18029			
D.	LABOUR & OVERHEADS (@ 26%)									
	1 Case 1. Standrad WAPDA 3-Phase					4947	6341	9729	13132	20530
	2. Case 2. Low Cost 3-Phase	2117	2458	2786	3222	3666	5217	8898	12444	19609
	3. Case 3 Low Cost 1-Phase	1688	2066	2460	2907	3270	4698			
E	TOTAL COST Rs									
	1 Case 1 Standrad WAPDA 3-Phase					23973	30728	47148	63641	99491
	2. Case 2. Low Cost 3-Phase	10260	11912	13500	15616	17765	25281	43122	60307	95030
	3 Case 3. Low Cost 1-Phase	8181	10011	11923	14087	15846	22717			

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TABLE T4-7

33/0.4 KV THREE PHASE AND SINGLE PHASE TRANSFORMERS

NO.	DESCRIPTION	COST Rs.									
		5 KVA	10	15	20	25	50	100	200	400	630
A.	TRANSFORMERS COST Rs										
	1. Case 1. Standrad WAPDA 3-Phase					24002	32579	47830	66625	107154	15553
	2. Case 2. Low Cost 3-Phase	9029	11126	13142	15830	18558	28102	45651	65365	104594	14592
	3. Case 3. Low Cost 1-Phase	7029	9352	11781	14528	16762	25486				
B.	SUBSTATIONS COST Rs										
	1. Case 1. Standrad WAPDA 3-Phase					4226	4226	7901	7901	7901	790
	2. Case 2. Low Cost 3-Phase	2625	2625	2625	2625	2625	2625	5977	5977	5977	597
	3. Case 3. Low Cost 1-Phase	2205	2205	2205	2205	2205	2205	4305	4305	4305	430
C.	TRANSFORMER & SUBSTATION COST Rs										
	1. Case 1. Standrad WAPDA 3-Phase					28228	36805	55731	74526	115055	163433
	2. Case 2. Low Cost 3-Phase	11654	13751	15767	18455	21183	30727	51628	71342	110571	151905
	3. Case 3. Low Cost 1-Phase	9234	11557	13986	16733	18967	27691				
D.	LABOUR & OVERHEADS (@ 28%)										
	1. Case 1. Standrad WAPDA 3-Phase					7904	10305	15605	20867	32215	45761
	2. Case 2. Low Cost 3-Phase	3263	3850	4415	5167	5931	8604	14456	19976	30960	42533
	3. Case 3. Low Cost 1-Phase	2586	3236	3916	4685	5311	7753				
E.	TOTAL COST Rs										
	1. Case 1. Standrad WAPDA 3-Phase					35132	47110	71336	95393	147270	209194
	2. Case 2. Low Cost 3-Phase	14917	17601	20182	23622	27114	39331	66084	91318	141531	194438
	3. Case 3. Low Cost 1-Phase	11820	14793	17902	21418	24278	35444				

COMMODORE\REMFR\33TRANS WK1

ANNEX T5

STANDARDS, SPECIFICATIONS AND COST OPTIMIZATION. CASE STUDIES

ANNEX - T5

STANDARDS, SPECIFICATIONS AND COST OPTIMISATION

1 SCOPE

A number of case studies were carried out to examine the influence of design standards, specifications and other measures on costs. Primarily, the following areas were covered:

- Poles
- HT conductors
- LT distribution
- Transformers
- HT versus LT
- Single phase versus three phase

2 POLES

Detailed study of different pole options is presented in a separate Report entitled "Design Study of Distribution Pole Options". The recommended span lengths for different types of poles are given in Annex T1. The costs of distribution lines using different poles are given in a report entitled "Detailed Analysis of Cost of Distribution Construction". The impact of low cost poles was studied on different lines using WAPDA's existing practice (i.e.existing spans) and improved practice (i.e allowable spans). These studies are given in Table T5-1 and T5-2. The maximum cost saving (w.r.t steel lattice structures) in the case of an average tubewell and village are as follows:-

	MAX. COST SAVINGS	
	Existing Practice	Improved Practice
. Average Tubewell	30%	28%
. Average Village	39%	40%

3 HT CONDUCTORS

The introduction of low cost conductor (mole) for a typical tubewell and a group of tubewells and villages was studied for both three phase (Table T5-3) and single phase options (Table T5-4). The results are summarised below:-

	CAPITAL COST SAVINGS w.r.t EXISTING PRACTICE	
	Three Phase Lines	Three Phase Main & Single Phase Branches
. Average Tubewell	62%	60%
. Group of Tubewell and Villages	46%	6%

The use of cheaper conductors can result in substantial cost savings both in terms of capital and net present worth.

4 LT DISTRIBUTION

A case study of bare conductors versus insulated conductors (Table T5-5) indicated that about 18% investment in capital can be saved through introduction of insulated conductors in LT distribution in villages.

Another case study (Table T5-6) examined the potential of cost savings through conversion of independent service cables to multi-service mains. About Rs. 170 per service can be saved by introduction of this method of connecton.

5 DISTRIBUTION TRANSFORMERS

Detailed design studies of distribution transformers are given in Annex T3. Two applications of low cost design of transformers were studied as follows:

- Cost savings due to slightly higher loss 25 kVA and 50 kVA transformers (Table T5-7)
- Cost savings due to smaller transformer sizes (Table T5-8)

The first study indicates that whereas the net savings in terms of present worth are negligible, the cost savings in capital can be of the order 13% and 22% for 25 kVA and 50 kVA high loss transformers.

The cost savings in terms of capacity savings may range from Rs. 5,000 to Rs. 10,000 per customer if the current waste of transformer capacity can be avoided.

6 THREE PHASE AND SINGLE PHASE HT VERSUS THREE PHASE LT

Two cases, namely three phase HT vs. Three phase LT (Table T5-9) and single phase HT vs. three phase LT (Table T5-10) were studied for electrificaton of 5, 10 and 15 HP tubewells for irrigation. The estimated cost savings in capital cost are summarised below:-

	CAPITAL COST SAVINGS %	
	3 Phase HT vs. 3-Phase LT	1-Phase HT vs. 3-Phase LT
. 5 HP Tubewell	20.4	28.5
. 10 HP Tubewell	12.4	12.5
. 15 HP Tubewell	30.0	23.6

The savings in terms of net present worth of capital, O & M and losses are even greater.

ANNEX - T5
STANDARD SPECIFICATIONS AND COST OPTIMIZATION. CASE STUDIES
LIST OF TABLES

Table T5-1: Case Studies for Technical Analysis
Existing WAPDA structures and existing span lengths vs. low cost structures (LCS) and maximum allowable spans

2: Case Studies for Technical Analysis
Existing WAPDA structures and maximum allowable span lengths vs. low cost structures (LCS) and maximum allowable spans

3: Case Studies for Technical Analysis
Existing WAPDA conductors for three phase HT and existing practice vs. low cost conductor for three phase HT and voltage regulators

4: Case studies for Technical Analysis
Existing WAPDA conductors for three phase HT and existing practice vs. low cost conductor for single phase HT and voltage regulators

5: Case Studies for Technical Analysis
Existing WAPDA bare conductors for three phase and single phase LT line and service cables vs. insulated LT conductors along the wall for a typical village

6: Case Studies for Technical Analysis
Existing WAPDA service connections for single phase customers through independent LT service cables vs. single phase cable mains along the wall for a typical LT line span for 10 single phase customers

7: Case Studies for Technical Analysis
Standard WAPDA 25 and 50 kVA, 11/0.4 kV transformers with existing loss standard vs. low cost transformers (LCT) with slightly higher losses

8: Case Studies for Technical Analysis
Standard WAPDA 25 kVA and 50 kVA 11/0.4 kV transformers vs. smaller transformers for tubewells for irrigation (TW) and small industry (SI)

9: Case Studies for Technical Analysis
Three phase HT vs. LT for tubewell electrification

10: Single phase HT vs. three phase LT for tubewell electrification

TABLE T5-1
CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA structures and existing span-lengths
vs low cost structures (LCS) and maximum allowable spans

NO.	DESCRIPTION	UNIT	QTY	COST Rs WAPDA SL	COST Rs WAPDA PSC	COST Rs LCS	COST SAVING SL Rs	COST SAVING SL %	COST SAVING PSC Rs	COST SAVING PSC %
A	3-PHASE 11 kV LINES PER km									
1	Gopher	km	1.00	66423	49901	36735	29688	45	13166	26
2.	Rabbit	"	1.00	83157	66635	54319	28838	35	12316	18
3.	Dog	"	1.00	117571	101048	93079	24492	21	7969	8
B	1-PHASE 11 kV LINES									
1	Gopher	"	1.00	58421	41899	26999	31422	54	14900	36
2.	Rabbit	"	1.00	69577	53055	39538	30039	43	13517	25
3	Dog	"	1.00	92519	75997	62480	30039	32	13517	18
C.	3-PHASE LT LINES PER km									
1.	Gnat	"	1.00	81900	49514	36948	44952	55	12566	25
2.	Ant	"	1.00	101226	68840	56274	44952	44	12566	18
3.	Wasp	"	1.00	142042	109657	100931	41111	29	8726	8
D.	1-PHASE LT LINES PER km									
1.	Gnat	"	1.00	69582	37196	24769	44813	64	12427	33
2.	Ant	"	1.00	79245	46859	34432	44813	57	12427	27
3.	Wasp	"	1.00	99653	67268	56335	43318	43	10933	16
E.	AVERAGE VILLAGE									
1.	3-phase LT line Wasp conductor	"	0.25	35511	27414	25233	10278	29	2181	8
2.	1-Phase LT line									
	a Gnat	"	0.40	27833	14878	9908	17925	64	4970	33
	b Ant	"	1.00	79245	46859	34432	44813	57	12427	27
	c Wasp	"	0.60	59792	40361	33801	25991	43	6560	16
Sub-total				202381	129512	103374	99007	49	26138	20
3	3-Phase HT line									
	a Dog	"	1.00	117571	101048	93079	24492	21	7969	8
	b Rabbit	"	0.50	41579	33318	27160	14419	35	6158	18
	c Gopher	"	0.50	33212	24951	18368	14844	45	6583	26
Sub-total				192362	159317	138607	53755	28	20710	13
Total				394743	288829	241981	152762	39	46848	16

F/662 CASE1A WK1

TABLE T5-1
CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA structures and existing span lengths
vs low cost structures (LCS) and maximum allowable spans

NO.	DESCRIPTION	UNIT	QTY	COST Rs			COST SAVING SL		COST SAVING PSC
				WAPDA SL	WAPDA PSC	LCS	Rs	%	Rs
F.	AVERAGE TUBEWELL								
1.	3-Phase HT line Gopher	"	0.25	16606	12475	9184	7422	45	3291
2.	3-Phase HT line Rabbit	"	0.25	20789	16653	13580	7210	35	3079
Total				37395	29134	22764	14632	39	6370

F/662 CASEIA WK17

TABLE T5 - 2

CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA structures and maximum allowable span lengths vs. low cost structures (LCS) and maximum allowable spans

NO	DESCRIPTION	UNIT	QTY	COST Rs			COST SAVING SL		COST SAVING PSC	
				WAPDA SL	WAPDA PSC	LCS	Rs	%	Rs	%
A	3-PHASE 11 kV LINES PER km									
1	Gopher	km	1.00	54116	42393	36735	17381	32	5658	13
2.	Rabbit	"	1.00	72368	60054	54319	18049	25	5735	10
3	Dog	"	1.00	111543	94476	93079	18464	17	1397	1
4	Panther	"	1.00	162114	134796	133088	29026	18	1708	1
B	1-PHASE 11 kV LINES									
1	Gopher	"	1.00	44951	33763	26999	17952	40	6764	20
2.	Rabbit	"	1.00	58949	46835	39538	19411	33	7097	15
3	Dog	"	1.00	81891	69577	62480	19411	24	7097	10
C	3-PHASE LT LINES PER km									
1	Gnat	"	1.00	67256	43121	36948	30308	45	6173	14
2.	Ant	"	1.00	86582	62447	56274	30308	35	6173	10
3.	Wasp	"	1.00	140543	104405	100931	39612	28	3474	3
D	1-PHASE LT LINES PER km									
1.	Gnat	"	1.00	55145	30941	24769	30376	55	6172	20
2.	Ant	"	1.00	64808	40604	34432	30376	47	6172	15
3	Wasp	"	1.00	85216	61012	56335	28881	34	4677	8
E	AVERAGE VILLAGE									
1	3-Phase LT line Wasp conductor	"	0.25	35136	26101	25233	9903	28	868	3
2	1-Phase LT line									
	a Gnat	"	0.40	22058	12376	9908	12150	55	2468	20
	b Ant	"	1.00	64808	40604	34432	30376	47	6172	15
	c Wasp	"	0.60	51130	36607	33801	17329	34	2806	8
Sub-total				173132	115688	103374	69758	40	12314	11

F/662 CASE1B WN1

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TABLE T5 - 2

CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA structures and maximum allowable span lengths vs. low cost structures (LCS) and maximum allowable spans

NO.	DESCRIPTION	UNIT	QTY	COST Rs			COST SAVING SL		COST SAVING PSC
				WAPDA SL	WAPDA PSC	LCS	Rs	%	Rs
3	3-Phase HT line								
	a. Dog	"	1.00	111543	94476	93079	18464	17	1397
	b. Rabbit	"	0.50	36184	30027	27160	9025	25	2867
	c Gopher	"	0.50	27058	21197	18368	8691	32	2829
Sub-total				174785	145700	138607	36180	21	7093
Total				347917	261388	241981	105938	30	19407
F.	AVERAGE TUBEWELL								
1.	3-Phase HT line Gopher	"	0.25	13529	10598	9184	4345	32	1414
2.	3-Phase HT line Rabbit	"	0.25	18092	15014	13580	4512	25	1434
Total				31621	25612	22764	8857	28	2848

F/662 CASE1B.WK1

TABLE T5-3

CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA conductors for three phase HT and existing practice vs. low cost conductor for three phase HT and voltage regulators

NO	DESCRIPTION	UNIT	RATE	QTY	COST Rs. Existing Standards & Practice	COST Rs. Low Cost Conductors	COST SAVINGS Rs	COST SAVINGS %
A.	AVERAGE TUBEWELL							
1.	Capital Cost 3 phase 11 kV Line							
	a Mole Conductor	km	25099	0.5	0	12550		
	b. Gopher	km	66423	0.5	33212	0		
	d. Voltage regulator	kVA		10	0	0		
	Total				33212	12550	20662	62
2.	Present Worth of Cost							
	a. Losses	Rs.			5	12		
	b. Capital Cost	Rs.			44172	16692		
	Total				44177	16704	27473	62
B.	GROUP OF TUBEWELLS AND VILLAGES							
1.	Capital Cost 3 Phase 11 kV							
	a.Mole	km	25099	4.01	0	100647		
	b.Gopher	km	66423	4.01	266356	0		
	c.Voltage Regulator	kVA	500	87	0	43500		
	Total				266356	144147	122209	46
2	Present Worth of Cost							
	a.Losses	Rs.			46720	93440		
	b.Capital cost	Rs.			354253	191716		
	Total				400973	285156	115817	29

FILE NAME CASE2A. (F / 662) /STS

TABLE T5 - 1

CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA conductors for three phase HT and existing practice vs low cost conductor for single phase HT and voltage regulators

NO	DESCRIPTION	UNIT	RATE	QTY	COST Rs. Existing Standards & Practice 3-PHASE	COST Rs. Low Cost Conductors 1-PHASE	COST SAVIN Rs
A	AVERAGE TUBEWELL						
1.	Capital Cost 11 kV Line						
	a. Mole Conductor (1-Phase)	km	20644	0.5	0	10322	
	b. Gopher (3-Phase)	km	66423	0.5	33212	0	
	c. Voltage regulator	kVA	500	0	0	0	
	d. Phase Convertor	kVA	300	10	0	3000	
	Total				33212	13322	19890
2.	Present Worth of Cost						
	a. Losses	Rs.			5	24	
	b. Capital Cost	Rs.			44172	17718	
	Total				44177	17742	26435
B	GROUP OF TUBEWELLS AND VILLAGES						
1.	Capital Cost 11 kV Line						
	a. Gopher 1-Phase	km	26999	2.87	0	77487	
	b. Gopher 3-Phase	km	66423	4.01	266356	0	
	c. Rabbit 1-Phase	km	39538	0.75	0	29654	
	d. Weasel 1-Phase	km	30219	1.75	0	52883	
	e. Voltage Regulator	kVA	500	0	0	0	
	f. Phase Converter	kVA	300	300	0	90000	
	Total				266356	250024	16332
2	Present Worth of Cost						
	a. Losses	Rs.			46720	93440	
	b. Capital cost	Rs.			354253	332532	
	Total				400973	425972	-24999

FILE NAME case1b WK1 (F / 862) /ST3

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TABLE T5 - 5

CASE STUDIES FOR-TECHNICAL ANALYSIS

Existing WAPDA bare conductors for three phase and single phase LT line and service cables vs insulated LT conductors along the wall for a typical village

NO	DESCRIPTION	UNIT	QTY	BARE CONDUCTOR (1) UNIT RATE	BARE CONDUCTOR (1) COST Rs	INSULATED CONDUCTOR (2) UNIT RATE	INSULATED CONDUCTOR (2) COST Rs	COST DIFFERENCE * Rs	COST DIFFERENCE * %
A	CAPITAL COST								
1	3-Phase LT line								
	a Gnat	Km	0.08	36948	2956	25577	2046	910	31
	b Ant	Km	0.12	56274	6753	47051	5646	1107	19
	c Wasp	Km	0.20	100931	20186	82403	18481	1705	9
2	1-Phase LT line								
	a Gnat	Km	0.32	24769	7926	12799	4092	3834	48
	b. Ant	Km.	0.48	34432	16527	23525	11292	5235	32
	c Wasp	Km.	0.80	56335	45068	46201	36961	8107	18
3	Service connections								
	a. Single phase	No	250	1200	300000	1000	250000	50000	17
	b Three phase	No.	3	3900	11700	3500	10500	1200	10
	Total				411116		339018	72098	18

* COST DIFFERENCE = (1) - (2)

Filename . case3a wk1 F / 662 MNN

TABLE T5 - 6

CASE STUDIES FOR TECHNICAL ANALYSIS

Existing WAPDA service connections for single phase customers through independent LT service cables vs. single phase cable mains along the wall for a typical LT line span for 10 single phase customers

NO.	DESCRIPTION	UNIT	RATE	QUANTITY / COST		COST SAVINGS	
				EXISTING PRACTICE	SERVICE CABLE MAIN	Rs.	%
A.	BILL OF QUANTITIES						
1.	2-Core Al cables.						
	a. 6 mm2 (7/0.044)	M	3.5	0	50		
	b. 10mm2 (7/0.052)	M	5.5	300	50		
	c. 16 mm2 (7/0.064)	M	8.8	0	50		
	d. 20 mm2 (19/0.044)	M	10	0	50		
2.	CONNECTION BOXES	NO.	50	0	10		
3.	CONNECTORS (PG-CLAMPS)	NO.	9	20	4		
4.	CABLE MASTS	NO.	200	10	1		
B.	COST ESTIMATE						
1.	2-Core Al. cables.						
	a. 6 mm2	Rs.		0	175		
	b. 10mm2	Rs.		1650	275		
	c. 16 mm2	Rs.		0	440		
	d. 20 mm2	Rs.		0	500		
2.	CONNECTION BOXES	Rs		0	500		
3.	CONNECTORS	Rs.		180	36		
4.	CABLE MASTS	Rs		2000	200		
	Total			3830	2126	1704	56

Filename :case3b.wk1 F / 662 MNN

TABLE T5 - 7

CASE STUDIES FOR TECHNICAL ANALYSIS

Standard WAPDA 25 and 50 kVA, 11/0.4 kV Transformers with Exisiting Loss Standard vs Low cost Transforemrs (LCT) with Slightly Higher Losses.

NO	DESCRIPTION	UNIT	RATE	QUANTITY/COST				COST SAVING 25 kVA		COST SAVING 50 kVA
				WAPDA 25 kVA 3-PHASE	WAPDA 50 kVA 3-PHASE	LCT 25 kVA 3-PHASE	LCT 50 kVA 3-PHASE	Rs	%	Rs
A	BILL OF QUANTITIES									
1.	Copper	kg	100	47	58	26	35			
2.	Silicone sheet	kg	40	69	110	65	123			
3.	Insulating material as % of copper cost	%		5	5	5	5			
4.	Transformer oil	gl	75	16	25	15.1	22.1			
5.	Steel sheet for tank	kg	11	40	61	41.1	52.9			
6.	Elliptical tube for cooling	M	12.75	20	30	19.2	37.8			
7.	11 kV bushing	No.	175	3	3	3	3			
8.	0.4 kV bushing	No	50	4	4	4	4			
9.	Tap charger	No.	200	1	1	1	1			
10.	Miscellaneous		200	1	1	1	1			
11.	Copper losses	kWH	2	1402	2562	1847	2547			
12.	Iron losses	kWH	2	1077	1533	1156	2129			
B	CAPITAL COST									
1.	Copper	kg.		4700	5800	2600	3600			
2.	Silicone sheet	kg.		2760	4400	2600	4920			
3.	Insulating material	%								
4.	Transformer oil	gl.		1200	1875	1133	1658			
5.	Steel sheet	kg.		440	671	452	581			
6.	Elliptical tube	No.		255	383	245	482			
7.	11 kV bushing	"		525	525	525	525			
8.	0.4 kV bushing	"		200	200	200	200			
9.	Tap charger	"		200	200	200	200			
10.	Miscellaneous			200	200	200	200			
	Total material cost			10480	14254	8154	12365	2326	22	1889
	Labour & overheads (40 %)			4192	5702	3262	4946			
	TOTAL COST			14672	19956	11416	17311	3256	22	2645

FILENAME : CASE4A WK1 F/662

TABLE T5 - 7

CASE STUDIES FOR TECHNICAL ANALYSIS

Standard WAPDA 25 and 50 kVA, 11/0.4 kV Transformers
with Exisiting Loss Standard vs. Low cost Transforemrs
LCT) with Slightly Higher Losses

NO.	DESCRIPTION	UNIT	RATE	QUANTITY/COST				COST SAVING 25 kVA		COST SAVING 50 kVA	
				WAPDA 25 kVA 3-PHASE	WAPDA 50 kVA 3-PHASE	LCT 25 kVA 3-PHASE	LCT 50 kVA 3-PHASE	Rs	%	Rs	
C	LOSSES										
	1 Copper losses			2804	5124	3694	5094				
	2. Iron losses			2154	3066	2312	4258				
	TOTAL			4958	8190	6006	9352	-1048	-21	-1162	-
D	PRESENT WORTH										
	1. Capital incl. O & M			19514	26541	15183	23024				
	2 Losses			33053	54600	40040	62347				
	TOTAL			52567	81141	55223	85371	-2656	-5	-4230	

FILENAME : CASE4A.WK1 F/662

TABLE T5 - 8

CASE STUDIES FOR TECHNICAL ANALYSIS

STANDARD WAPDA 25 kVA, 50 kVA & 11/0.4 kV TRANSFORMERS VS. SMALLER TRANSFORMERS FOR TUBEWELL FOR IRRIGATION (TW) AND SMALLL INDUSTRY (SI)

No.	DESCRIPTION	UNIT	WAPDA STANDARD TRANSFORMERS			SMALLER TRANSFORMERS		
			QTY	RATE	COST	QTY	RATE	COST
A	BILL OF QUANTITIES							
	1. 5 HP TW (WAPDA : 25 kVA)	No.	0.25	23973	5993	1	10260	10260
	2. 7.5 HP TW (WAPDA : 25 kVA)	No.	0.5	23973	11987	1	11912	11912
	3. 10 HP TW (WAPDA : 25 kVA)	No.	0.5	23973	11987	1	11912	11912
	4. 15 HP TW / SI (WAPDA : 25 kVA)	No.	1	23973	23973	1	13500	13500
	5. 20 HP TW / SI (WAPDA : 25 kVA)	No.	1	23973	23973	1	15616	15616

Filename : CASE4B WK1 F / 662

TABLE T5 - 9

CASE STUDIES FOR TECHNICAL ANALYSIS

THREE PHASE HT VS. LT FOR TUBEWELL ELECTRIFICATION

No	DESCRIPTION	UNIT	3-PHASE HT (1) QTY	RATE	COST	3-PHASE LT (2) QTY	RATE	COST	COST DIFFEREN (2) - (1) Rs	%
A	CAPITAL COST									
	5 HP TUBEWELL									
1.	Line									
	a. HT Mole	km	0.25	25099	6275	0	0	0		
	b. LT Gnat	km	0	0	0	0.25	36948	9237		
2.	Distribution transformers Substation	kVA	5	2052	10260	5	2305	11525		
	Total				16535			20762	4227	20
	10 HP TUBEWELL									
1.	Line									
	a. HT Mole	Km	0.25	25099	6275	0	0	0		
	b. LT Gnat	Km	0	36948	0	0.25	36948	9237		
2.	Distribution transformers Substation	kVA	10	1191	11910	10	1152.50	11525		
	Total				18185			20762	2577	12
	15 HP TUBEWELL									
1	Line									
	a. HT Mole	km	0.25	25099	6275	0	0	0		
	b. LT Gnat	Km	0	36948	0	0.25	36948	9237		
2.	Distribution transformers Substation (15 kVA)	No.	15	900	13500	15	1268.3	19025		
	Total				19775			28262	8487	30

Filename : case5a.wk1 f / 662 MNN

TABLE T5 - 9

CASE STUDIES FOR TECHNICAL ANALYSIS

THREE PHASE HT VS LT FOR TUBEWELL ELECTRIFICATION

No	DESCRIPTION	UNIT	3-PHASE HT (1) QTY	RATE	COST	3-PHASE LT (2) QTY	RATE	COST	COST DIFFERENCE (2) - (1) Rs	%
B.	LOSSES (kWH)									
	1. 5 HP	kWH	0.128	2	0.3	38.7	2	77		
	2. 10 HP	kWH	0.515	2	1	154.7	2	309		
	3. 15 HP	kWH	1.157	2	2.3	348.7	2	697		
	Total				3.6			1083	1079	99.6
C.	PRESENT WORTH ANALYSIS									
	1. 5 HP									
	a. Capital	Rs.			21992			27613		
	b. Losses	Rs.			2			513		
	Total				21994			28126	6132	21.8
	2. 10 HP									
	a. Capital	Rs.			24186			27613		
	b. Losses	Rs.			7			2060		
	Total				24193			29673	5480	18.5
	3. 15 HP									
	a. Capital	Rs.			26301			37588		
	b. Losses	Rs.			15			4647		
	Total				26316			42235	15919	37.7

k Cost of 3-Phase Standard transformers and Substations

	Cost/kVA Transformer	Transformer cost	Substation cost	Total cost	Average cost/kVA
5 HP	1500	7500	4025	11525	2305
10 HP	750	7500	4025	11525	1152.5
15 HP	1000	15000	4025	19025	1268.3

Filename : case5a.wk1 f / 662 MNN

TABLE T5 - 10

CASE STUDIES FOR TECHNICAL ANALYSIS

SINGLE PHASE HT VS. THREE PHASE LT FOR TUBEWELL ELECTRIFICATION

No.	DESCRIPTION	UNIT	1-PHASE HT (1) QTY	RATE	COST	3-PHASE LT (2) QTY	RATE	COST	COST DIFFERE (2) - (1) Rs.	
A	CAPITAL COST									
	5 HP TUBEWELL									
1	Line									
	a HT Mole	Km	0.25	20644	5161	0	0	0		
	b. LT Gnat	Km	0	0	0	0.25	36948	9237		
2.	Distribution Transformer Substation	kVA	5	1636	8180	5	2305	11525		
3.	Phase Converter	kVA	5	300	1500	0	0	0		
	Total				14841			20762	5921	2
	10 HP TUBEWELL									
1.	Line									
	a. HT Mole	Km	0.25	20644	5161	0	0	0		
	b. LT Gnat	Km	0	0	0	0.25	36948	9237		
2.	Distribution Transformer Substation	kVA	10	1001	10010	10	1152.50	11525		
3	Phase Converter	kVA	10	300	3000	0	0	0		
	Total				18171			20762	2591	1
	15 HP TUBEWELL									
1	Line									
	a. HT Mole	Km	0.25	20644	5161	0	0	0		
	b. LT Gnat	Km	0	0	0	0.25	36948	9237		
2.	Distribution Transformer Substation	kVA	15	795	11925	15	1268.3	19025		
3.	Phase Converter	kVA	15	300	4500	0	0	0		
	Total				21586			28262	6676	1

Filename: Case5b.wk1 F / 662 MNN

TABLE T5 - 10

CASE STUDIES FOR TECHNICAL ANALYSIS

SINGLE PHASE HT VS. THREE PHASE LT FOR TUBEWELL ELECTRIFICATION

No	DESCRIPTION		1-PHASE HT (1)			3-PHASE LT (2)			COST DIFFERENCE (2) - (1)	
		UNIT	QTY	RATE	COST	QTY	RATE	COST	Rs	%
B.	LOSSES (kWH)									
	1. 5 HP	kWH	.0 256	2	0.5	38.7	2	77		
	2. 10 HP	kWH	1 03	2	2 1	154 7	2	309		
	3 15 HP	kWH	2 314	2	4.6	348 7	2	697		
	Total				7.2			1083	1076	99.4
C.	PRESENT WORTH ANALYSIS									
	1. 5 HP									
	a. Capital	Rs.			19739			27613		
	b. Losses	Rs.			3			513		
	Total				19742			28126	8384	29.8
	2. 10 HP									
	a. Capital	Rs.			24167			27613		
	b. Losses	Rs.			14			2060		
	Total				24181			29673	5492	18.5
	3 15 HP									
	a Capital	Rs.			28709			37588		
	b Losses	Rs.			31			4647		
	Total				28740			42235	13495	32

k Cost of 3-Phase Standard transformers and Substations

	Cost/kVA Transformer	Transformer cost	Substation cost	Total cost	Average cost/kVA
5 HP	1500	7500	4025	11525	2305
10 HP	750	7500	4025	11525	1152.5
15 HP	1000	15000	4025	19025	1268.3

Filename: Case5b.wk1 F / 662 MNN

ANNEX T6
SYSTEM APPLICATIONS FOR TECHNICAL OPTIONS. CASE STUDIES

ANNEX T6

SYSTEM APPLICATIONS FOR TECHNICAL OPTIONS. CASE STUDIES

1 SCOPE

The following types of case studies are included in this Annex.

- Choice of primary voltage
- Design of lines for year 5, 10, 15 and 20
- Rural Electrification Intensification versus Expansion
- Decentralised generation options for a typical tubewell, village and area in each province

2 CHOICE OF PRIMARY VOLTAGE

In two sample areas, one in Tehsil Okara, District Okara in Punjab and one in Tehsil Kalat, District Kalat in Baluchistan, the 11 kV and 33 kV networks were designed and analysed to determine the best conductor selection with respect to maximum voltage drop (7.5%) and optimisation of cost of capital, O & M and energy losses . The cost estimates were based on the low cost distribution poles, transformers. etc.

The detailed technical analysis of these two areas is given in a separate study entitled " Design of netwrok configurations in sample areas". The cost estimates of the proposed 11 kV and 33 kV distribution networks were prepared on the basis of the results of these studies. These estimates are summarised in Tables T6-1 and T6-2.

The network configurations in the case of sample areas Tehsil Thatta, District Thatta, Sind and Tehsil Lakki Marwat, District Bannu, NWFP, were developed on similar lines as for the two areas in Punjab and Baluchistan. However, estimates of cost were based on conclusions drawn from the previous studies regarding distribution line lengths by conductor sizes and energy losses as percentages of expected demand. Summary of cost estimates for 11 kV vs. 33 kV networks in the Thatta and Lakki Marwat areas is given in Tables T6-5 and T6-6.

All the case studies indicate that 33 kV is a more cost effective solution both in terms of capital investment and net present worth of costs. The main points of the cost comparisons are summarised below.

	Punjab Okara	Baluchistan Kalat	Sind Thatta	NWFP Lakki Marwat
1. Length of Lines. km				
- 11 kV	2,164	1,857	670	444
- 33 kV	2,113	1,859	607	392
2. Number of Transformers	3,686	2,701	602	570
3. Capacitors. kVA	22,430	7,088	6,593	8,218
4. Voltage Regulators. kVA				
- 11 kV	910	2,414	2,253	2,808
- 33 kV	5,196	1,741	1,755	2,188
5. Substation. MVA	60	30	30	35
6. 132 kV Transmission Lines Length. km				
- 11 kV	90	35	70	44
- 33 kV	20.5	17.5	43	33
7. Energy Losses. MWh				
- 11 kV	3,165	1,777	1,659	2,067
- 33 kV	574	167	169	210
8. Capital Cost Rs.(000)				
- 11 kV	304,295	177,218	155,752	156,551
- 33 kV	251,115	167,433	117,212	126,653
9. Net Present Worth of Costs				
- 11 kV	446,905	259,393	229,263	235,780
- 33 kV	341,636	224,913	158,139	171,248
10. Savings due to 33 kV				
- Capital %	17	6	25	19
- Net Present Worth%	24	13	31	27

The analysis indicates saving in capital investment ranging between 6% and 25% and in net present worth of costs between 13% and 31%. A major part of the saving is due to the reduction in transmission line lengths and number of 11 kV grid stations.

As may be seen, the energy losses are drastically reduced and contribute to large savings in net present worth of costs.

REMPRT6.ANX (F/517)

TABLE T6-15

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL RURAL AREA IN BALUCHISTAN

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	CENTRAL GRID
	PARAMETERS					
	TUBEWELL HP	10 HP				
	EFF FOR WIND GEN	0 85 %				
	DIESEL ENG. BASE EFF	0 175 pu				
	DIESEL CONSUMPTION	350 gm/BHP/Hr				
	CF AT CUSTOMER	0 76470				
	LOAD FACTOR	2015 Hrs				
	COSTS:					
	- DIESEL GENERATOR	4200 RS/KW				
	- WIND GENERATOR	25500 RS/KW				
	- PV ARRAY	138000 RS/KW				
	- BATTERY FOR PV	3440 RS/KWH				
	- MICRO HYDEL	27000 RS/KW				
	- GENE./TRANS/DIST	36000 RS/KW				
	- DIESEL/LITRE	3 5 RS/LITRE				
	- ENGINE OIL/LITRE	8 RS/LITRE				
	- ELECTRICITY	0 61 RS/KWH				
	O&M					
	- DIESEL	0 2 pu				
	- WIND	0 05 pu				
	- MICRO HYDEL	0.05 pu				
	- CENTRAL GRID	0 05 pu				
	DIESEL CONSUMPTION	2052877 LITRES				
	OF	0 1 pu				

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3 BASIS OF DESIGN

A case study of a grid station in Tehsil Okara was carried out to see the impact of demand in year 5, 10, 15 and 20 on voltage drops and net present worth of costs by feeders which were designed on the basis of demand in year 10. Both three phase and single phase configurations were studied. The detailed analysis of this grid station is given in a separate report entitled "ANALYSIS OF BASIS OF DISTRIBUTION LINE DESIGN IN A SAMPLE AREA". The results are summarised in Table T6-3. The following conclusions can be drawn from this study.

- Both 3-phase and 1-phase lines, designed for demand in year 10, will need rehabilitation by year 15.

- The cost of single phase option on branch lines and three phase lines on main feeder is comparable with three phase line

  The present worth of additional losses between year 10 and 20 is such that it will be more economical to rehabilitate the system after year 10.

4 INTENSIFICATION VERSUS EXPANSION

Four different alternatives of rural electrification were studied for a sample area:

Expansion — New area. 260 villages
All new villages to be electrified
At least 70% domestic connections to be provided with connections

Intensification:
(1) Electrification in existing electrified villages only. No HT line. 260 villages

(2) Electrification in selected non-electrified villages close to line only. 1.5 km HT/village. 70 villages

(3) Electrification in all remaining villages. 2.5 km HT/village.142 villages

The capital investment per kW and per customer (Table T6-4) for the four cases, alongwith the benefit cost ratio is summarised below:-

	Expansion in new area	Intensification		
		No HT	1.5 km HT/village	2.5 km HT/villge
. Cost/kW. Rs.	4,983	3,089	4,714	4,893
. Cost/customer Rs.	3,598	1,794	3,402	3,533

Benefit-cost ratio	0.959	1.530	1.013	0.976

The best return on capital can be obtained by increasing the customer saturation in already electrified villages and connecting villages close to existing distribution lines. Intensification in existing electrified area, to cover all villages, or expansion in a new area has the lowest benefit-cost ratio.

5. DECENTRALIZED GENERATION

Three types of case studies were carried out

(1) Tubewell. A typical case
(2) Typical village in each province
(3) Typical area in each province

These studies are given in tables T6-7 to T6-15. The costs/kWh delivered are summarized below:

	Cost/kWh Delivered (Rupees)				
	Diesel	Solar	Wind	Micro Hydel	Central Grid
. Tubewell	3.30	16.40	8.04	3.58	-
. Village					
Punjab	3.97	13.26	3.41	2.47	2.80
Sind	4.29	15.66	4.03	2.91	3.22
NWFP	3.73	10.60	2.73	1.97	2.38
Baluchistan	7.08	14.90	4.03	-	4.92
. Area					
Punjab	3.54	10.57	2.70	1.97	2.29
Sind	3.72	12.58	3.21	2.35	2.61
NWFP	3.35	8.52	2.17	1.59	1.96
Baluchistan	3.62	11.49	2.93	-	2.80

The following conclusions can be drawn from these studies.

At the prevailing costs, solar is not attractive either for a tubewell, village or area electrification. The economics for households with very little demand may be attractive specially in far flung areas.

Microhydel and small hydel (cost Rs. 25,000 - 30,000 per kW) is an attractive decentralized option.

The central grid, at prevailing costs and average conditions, is an attractive solution. However, even diesel generation is an interesting option worth investigation.

For areas which require larger transmission lines and thereby higher costs, the economics of diesel generation, small hydel (if available) and wind power should be investigated thoroughly. The choice of the option will be project specific and detailed studies should be carried out in each case.

ANNEX - T6
APPLICATIONS FOR TECHNICAL OPTIONS. CASE STUDIES
LIST OF TABLES

Table T6-1 : Choice of primary voltage (11 kV or 33 kV) in Punjab. District Okara, Tehsil Okara

2 : Choice of primary voltage (11 kV or 33 kV) Baluchistan. District Kalat, Tehsil Kalat

3 : Summary of capital investment, energy losses and preser worth analysis of cost for design of lines for demand ir year 5,10,15 and 20 . Grid station GS-9. Tehsil Okara

4 : Rural Electrification expansion and intensification in a typical area in Punjab. District Okara. Tehsil Okara.

5 : Choice of primary voltage (11 kV or 33 kV) in Sind. District Thatta. Tehsil Thatta.

6 : Choice of primary voltage (11 kV or 33 kV) in NWFP. District Bannu. Tehsil Lakki Marwat

7 : Decentralized generation options for Electrification of a typical tubewell (10 HP)

8 : Decentralized generation options for Electrification of a typical village in Punjab

9 : Decentralized generation options for Electrification of a typical village in Sind

10 : Decentralized generation options for Electrification of a typical village in NWFP

11 : Decentralized generation options for Electrification of a typical village in Baluchistan

12 : Decentralized generation options for Electrification of a typical rural area in Punjab

13 : Decentralized generation options for Electrification of a typical rural area in Sind.

14 : Decentralized generation options for Electrification of a typical rural area in NWFP

15 : Decentralized generation options for Electrification of a typical rural area in Baluchistan

TABLE T6 - 1

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN PUNJAB. DISTRICT OKARA. TEHSIL OKARA.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
A	CAPITAL COST									
1.	HT LINES (3-Phase)									
	a. Mole	Km.	1609.5	25099	40397	1900.34	30119	57236	-16839	-42
	b. Squirrel	Km	43.95	34000	1494	29.27	40800	1194	300	20
	c. Gopher	Km.	78.15	36735	2871	38.18	44082	1683	1188	41
	d. Weasel	Km	19.34	40591	785	5.13	48709	250	535	68
	e. Rabbit	Km	128.81	54319	6997	67.81	65183	4420	2577	37
	f. Dog	Km	284.4	93078	26471	72.81	111694	8132	18339	69
	g. Panther	Km.	0	133088	0	0.00	159706	0	0	0
	Total		2164.15		79015	2113.54		72915	6100	8
2.	DISTRIBUTION TRANSFORMERS									
	a. 5 kVA	No	400	10260	4104	400	14917	5967	-1863	-45
	b. 10 kVA	No.	951	11912	11328	951	17601	16739	-5411	-48
	c. 15 kVA	No	570	13500	7695	570	20182	11504	-3809	-49
	d. 20 kVA	No	614	15616	9588	614	23622	14504	-4916	-51
	e. 25 kVA	No	154	17765	2736	154	27114	4176	-1440	-53
	f. 50 kVA	No.	712	25231	18000	712	39331	28004	-10004	-56
	g. 100 kVA	No	214	43122	9228	214	66084	14142	-4914	-53
	h. 200 kVA	No	71	60307	4282	71	91318	6484	-2202	-51
	Total		3686		66961	3686		101520	-34559	-52
3	CAPACITORS									
	a. Switched	kVAr	7477	200	1495	7477	240	1794	-299	-20
	b. Fixed	kVAr	14953	125	1869	14953	150	2243	-374	-20
4.	AUTOMATIC VOLTAGE REGULATORS	kVA	910	500	455	5196	600	3118	-2663	-585

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TABLE T6 - 1

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN PUNJAB. DISTRICT OKARA. TEHSIL OKARA.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
5	SUBSTATION COST (132/11 & 132/33)	MVA	60	1000000	60000	60	800000	48000	12000	20
6.	TRANSMISSION LINE COST (132 kV)	KM	90	1050000	94500	20.5	1050000	21525	72975	77
	Total Capital Cost				304295			251115	53180	17
7.	ENERGY LOSSES	KWH	3164600	2	6329	574[illegible]	2	1148	5181	82
8.	PRESENT WORTH OF COSTS									
	1. Energy Losses	Rs.(000)			42193			7653	34540	82
	2. Capital Including O & M	Rs (000)			404712			333983	70729	17
	Total				446905			341636	105269	24

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TABLE T6 - 2

CASE STUDIES FOR TECHNICAL ANALYSI

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN BALUCHISTAN. DISTRICT KALAT. TEHSIL KALAT.

No	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
A.	CAPITAL COST									
1.	HT LINES (3-Phase)									
	a. Mole	Km.	1545.95	25099	38802	1689.17	30119	50876	-12074	-31
	b. Squirrel	Km.	6.14	34000	209	58.78	40800	2398	-2189	-1047
	c. Gopher	Km.	51.14	36735	1879	30.26	44082	1334	545	29
	d. Weasel	Km.	6.25	40591	254	0.00	48709	0	254	100
	e. Rabbit	Km.	38.2	54319	2075	44.03	65183	2870	-795	-38
	f. Dog	Km.	65.03	93078	6053	10.26	111694	1146	4907	81
	g. Panther	Km.	143.95	133088	19158	26.50	159706	4232	14926	78
	Total		1856.66		68430	1859		62856	5574	8
2.	DISTRIBUTION TRANSFORMERS									
	a. 5 kVA	No.	76	10260	780	76	14917	1134	-354	-45
	b. 10 kVA	No.	460	11912	5480	460	17601	8096	-2616	-48
	c. 15 kVA	No.	553	13500	7466	553	20182	11161	-3695	-49
	d. 20 kVA	No.	1250	15616	19520	1250	23622	29528	-10008	-51
	e. 25 kVA	No.	350	17765	6218	350	27114	9490	-3272	-53
	f. 50 kVA	No.	12	25281	303	12	39331	472	-169	-56
	g. 100 kVA	No.	0	43122	0	0	66084	0	0	0
	h. 200 kVA	No.	0	60307	0	0	91318	0	0	0
	Total		2701		39767	2701		59881	-20114	-51
3.	CAPACITORS									
	a. Switched	kVAr	2363	200	473	2363	240	567	-94	-20
	b. Fixed	kVAr	4725	125	591	4725	150	709	-118	-20
4.	AUTOMATIC VOLTAGE REGULATORS	kVA	2414	500	1207	1741	600	1045	162	13

File Name: TABLE6-2.wk1 F / 662

TABLE T6 - 2

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN BALUCHISTAN. DISTRICT KALAT. TEHSIL KALAT.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
5.	SUBSTATION COST (132/11 & 132/33)	MVA	30	1000000	30000	30	800000	24000	6000	20
6.	TRANSMISSION LINE COST (132 kV)	km	35	1050000	36750	17.5	1050000	18375	18375	50
	Total Capital Cost				177218			167433	9785	6
7.	ENERGY LOSSES	kWH	1777140	2	3554	167230	2	334	3220	91
8.	PRESENT WORTH OF COSTS									
	1.Energy Losses	Rs.(000)			23693			2227	21466	91
	2. Capital (Including O & M)	Rs.(000)			235700			222686	13014	6
	Total				259393			224913	34480	13

File Name: TABLE6-2.wk1 F / 662

TABLE T6-3
SUMMARY OF CAPITAL INVESTMENT ENERGY LOSSES AND PRESENT WORTH ANALYSIS OF COSTS FOR DESIGN OF LINES FOR DEMAND IN YEAR 5,10,15 AND 20. GRID STATION GS-9. TEHSIL OKARA

NO.	FEEDER NO.	CAPITAL PW	DEMAND YR 5		DEMAND YR 10		DEMAND YR 15		DEMAND YR 20	
			VD%	NPWC	VD%	NPWC	VD%	NPWC	VD%	NPWC
1.	F1- 3-ph	836	5.0	1,727	7.0	2,183	9.2	3,012	11.9	4,320
	1-ph	911	5.1	1,741	7.1	2,170	-	-	-	-
2.	F2- 3-ph	580	4.1	1,076	5.8	1,390	7.7	1,867	9.9	2,624
	1-ph	575	5.0	1,076	6.9	1,377	-	-	-	-
3	F3- 3-ph	1,129	5.0	2,048	6.7	2,530	9.2	3,382	11.9	4,691
	1-ph	1,150	5.2	2,076	7.3	2,522	-	-	-	-
4.	F4- 3-ph	1,205	5.0	2,181	6.9	2,724	9.2	3,668	11.8	5,120
	1-ph	1,217	5.0	2,197	7.0	2,717	-	-	-	-
5.	F5- 3-ph	993	5.2	1,814	6.8	2,238	8.9	2,933	11.5	4,022
	1-ph	1,013	5.2	1,805	6.8	2,241	-	-	-	-
6.	F6- 3-ph	1,742	1.2	3,654	4.8	4,757	8.9	6,520	13.4	9,264
	1-ph	1,783	4.5	3,676	6.0	4,761	-	-	-	-
7.	F7- 3-ph	1,491	5.5	2,905	7.0	3,657	8.7	4,787	10.7	6,552
	1-ph	1,548	5.2	2,930	6.7	3,682	-	-	-	-
8.	F8- 3-ph	938	4.4	1,941	5.4	2,299	6.5	2,876	7.8	3,705
	1-ph	942	4.6	1,970	7.9	2,344	-	-	-	-
9.	F9- 3-ph	335	3.6	668	4.0	715	4.5	831	5.1	936
	1-ph	337	4.0	663	4.	710	-	-	-	-

TABLE T6 - 4

CASE STUDIES FOR TECHNICAL ANALYSIS

RURAL ELECTRIFICATION EXPANSION AND INTENSIFICATION
IN TYPICAL AREA IN PUNJAB. DISTRICT OKARA. TEHSIL OKARA.

NO.	DESCRIPTION	UNIT	QUANTITIES / COST			
			EXPANSION NEW AREA	INTENSIFICATION		
				Electrification in Existing Electrified Villages only	Electrification in selected Non Electrified Villages close to line only	Electrifica in all rema Non Electri Villages
1.	No. of Villages to be Electrified	No.	260	118	70	142
2.	Potential Customers					
	a. Single Phase	No.	100349	43384	27017	54806
	b. Three Phase Small Industry & Water Supply Tubewells	No.	432	194	116	236
	c. Three Phase Irrigation Tubewells	No.	2329	822	627	1272
3.	Existing Customers					
	a. Single Phase	No.	0	10942	0	0
	b. Three Phase Small Industry & Water Supply Tubewells	No.	0	194	0	0
	c. Three Phase Irrigation Tubewells	No.	0	419	0	0
4.	Additional Customers					
	a. Single Phase	No.	70244	19427	18912	38364
	b. Three Phase Small Industry & Water Supply Tubewells	No.	432	0	116	236
	c Three Phase Irrigation Tubewells	No.	2329	403	627	1272
	Total		73005	19830	19655	39872
5.	Additional Demand at distribution level					
	a Single Phase (@ 0.417 kW)	kW	29292	8101	7886	15998
	b Three Phase (@ 8.48 kW)	kW	23413	3417	6301	12788
	Total	kW	52705	11518	14187	28786

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TABLE T6 - 4

CASE STUDIES FOR TECHNICAL ANALYSIS

RURAL ELECTRIFICATION EXPANSION AND INTENSIFICATION
IN TYPICAL AREA IN PUNJAB. DISTRICT OKARA. TEHSIL OKARA.

NO.	DESCRIPTION	UNIT	QUANTITIES / COST			
			EXPANSION NEW AREA	INTENSIFICATION		
				Electrification in Existing Electrified Villages only	Electrification in selected Non Electrified Villages close to line only	Electrificat in all remai Non Electrif Villages
6.	Additional Capital Investment					
	a. 11 kV lines (@ Rs. 36510/kM)					
	- Villages	Rs.(000)	28478 *	0	3834 **	12961 *
	- Tubewells	Rs.(000)	45917	7945	12362	25078
	b. Distribution transformers (@ Rs. 620/kVA)	Rs.(000)	42966	2786	11566	23467
	c. 0.4 kV lines (@ Rs. 97100/kM) (@ 2 kM / Village)	Rs.(000)	50492	0	13594	27576
	d. Single Phase Customers (@ Rs. 1200)	Rs.(000)	84293	23312	22694	46037
	e. Three phase Small Industry (@ Rs. 3800)	Rs.(000)	1642	0	441	897
	f. Three phase Tubewells (@ Rs. 3800)	Rs.(000)	8850	1531	2383	4834
	Total	Rs.(000)	262638	35574	66874	140850
9.	Additional Energy Consumption					
	a. Single Phase (@ 550 kWH)	MWH-	38634	10685	10402	21100
	b. Three Phase (@ 12000 kWH)	MWH	33132	4836	8916	18096
	Total		71766	15521	19318	39196
10.	Additional Revenue (@ Rs. 0.70/kWH)	Rs.(000)	50236	10865	13523	27437
11.	Revenue per kW	Rs.	953	943	953	953
12.	Capital cost per kW	Rs.	4983	3089	4714	4893
13.	Capital cost per Customer	Rs.	3598	1794	3402	3533

File Name : TABLE6-4.wk1 F / 662 MNN

TABLE T6 - 1

CASE STUDIES FOR TECHNICAL ANALYSIS

RURAL ELECTRIFICATION EXPANSION AND INTENSIFICATION
IN TYPICAL AREA IN PUNJAB. DISTRICT OKARA. TEHSIL OKARA.

NO.	DESCRIPTION	UNIT	QUANTITIES / COST			
			EXPANSION NEW AREA	INTENSIFICATION		
				Electrification in Existing Electrified Villages only	Electrification in selected Non Electrified Villages close to line only	Electrifica in all rema Non Electri Villages
14.	Present Worth per kW Installed Capacity					
	a. Capital Investment	Rs.	6627	4108	6270	6508
	b. Revenue	Rs.	6353	6287	6353	6353
	c. Benefit-Cost Ratio		0.959	1.53	1.013	0.976

* 260 Villages @ 3 kM
** 70 Villages @ 1.5 kM
*** 142 Villages @ 2.5 kM

File Name : TABLE6-4.wk1 F / 662 MNN

TABLE T6 - 5

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN SINO. DISTRICT THATTA. TEHSIL THATTA.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
A.	CAPITAL COST									
	HT LINES (3-Phase)									
	a. Mole	Km.	396.58	25099	9954	457.80	30119	13788	-3834	-39
	b Squirrel	Km	5.41	34000	184	51.72	40800	2110	-1926	-1047
	c Gopher	Km	44.97	36735	1652	26.62	44082	1173	479	29
	d Weasel	Km	5.49	40591	223	0.00	48709	0	223	100
	e Rabbit	Km	33.59	54319	1825	38.73	65183	2525	-700	-38
	f Dog	Km	57.21	93078	5325	9.02	111694	1007	4318	81
	g. Panther	Km	126.59	133088	16848	23.29	159706	3720	13128	78
	Total		663.84		36011	607.18		24323	11688	32
2.	DISTRIBUTION TRANSFORMERS									
	a. 5 kVA	No	18	10260	185	18	14917	269	-84	-45
	b. 10 kVA	No	39	11912	465	39	17601	686	-221	-48
	c 15 kVA	No	88	13500	1188	88	20182	1776	-588	-49
	d 20 kVA	No	183	15616	2858	183	23622	4323	-1465	-51
	e 25 kVA	No	62	17765	1101	62	27114	1681	-580	-53
	f 50 kVA	No	89	25281	2250	89	39331	3500	-1250	-56
	g 100 kVA	No	78	43122	3364	78	66084	5155	-1791	-53
	h 200 kVA	No	45	60307	2714	45	91318	4109	-1395	-51
	Total		602		14125	602		21499	-7374	-52
3	CAPACITORS									
	a. Switched	kVAr	2198	200	440	2198	240	528	-88	-20
	b Fixed	kVAr	4395	125	549	4395	150	659	-110	-20
4.	AUTOMATIC VOLTAGE REGULATORS	kVA	2253	500	1127	1755	600	1053	74	7

File Name: TABLE6-5.wk1 F / 662

TABLE T6 - 5

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN SINO. DISTRICT THATTA. TEHSIL THATTA.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
5	SUBSTATION COST (132/11 & 132/33)	MVA	30	1000000	30000	30	800000	24000	6000	20
6.	TRANSMISSION LINE COST (132 kV)	Km	70	1050000	73500	43	1050000	45150	28350	39
	Total Capital Cost				155752			117212	38540	25
7	ENERGY LOSSES	KWH	1658579	2	3317	168564	2	337	2980	90
8.	PRESENT WORTH OF COSTS									
	1.Energy Losses	Rs.(000)			22113			2247	19866	90
	2. Capital (Including O & M)	Rs.(000)			207150			155892	51258	25
	Total				229263			158139	71124	31

File Name: TABLE6-5.wk1 F / 662

TABLE T6 - 6

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN NWFP. DISTRICT BANNU. TEHSIL LAKKI MARWAT.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
A.	CAPITAL COST									
1.	HT LINES (3-Phase)									
	a. Mole	Km.	470.5	25099	11809	633.40	30119	19077	-7268	-62
	b. Squirrel	Km.	9.4	34000	320	89.50	40800	3652	-3332	-1041
	c. Gopher	Km.	77.9	36735	2862	46.10	44082	2032	830	29
	d. Weasel	Km.	9.5	40591	386	0.00	48709	0	386	100
	e. Rabbit	Km.	58.2	54319	3161	67.10	65183	4374	-1213	-38
	f. Dog	Km.	99.1	93078	9224	15.60	111694	1742	7482	81
	g. Panther	Km.	219.4	133088	29200	40.30	159706	6436	22764	78
	Total		944.00		56962	892.00		37313	19649	34
2.	DISTRIBUTION TRANSFORMERS									
	a. 5 kVA	No.	229	10260	2350	229	14917	3416	-1066	-45
	b. 10 kVA	No.	64	11912	762	64	17601	1126	-364	-48
	c. 15 kVA	No.	15	13500	203	15	20182	303	-100	-49
	d. 20 kVA	No.	13	15616	203	13	23622	307	-104	-51
	e. 25 kVA	No.	68	17765	1208	68	27114	1844	-636	-53
	f. 50 kVA	No.	118	25281	2983	118	39331	4641	-1658	-56
	g. 100 kVA	No.	104	43122	4485	104	66084	6873	-2389	-53
	h. 200 kVA	No.	59	60307	3558	59	91318	5388	-1830	-51
	Total		670		15752	670		23898	-8146	-52
3.	CAPACITORS									
	a. Switched	kVAr	2739	200	548	2739	240	657	-109	-20
	b. Fixed	kVAr	5479	125	685	5479	150	822	-137	-20
4.	AUTOMATIC VOLTAGE REGULATORS	kVA	2808	500	1404	2188	600	1313	91	6

File Name: TABLE6-6.wk1 F / 662

TABLE T6 - 6

CASE STUDIES FOR TECHNICAL ANALYSIS

CHOICE OF PRIMARY VOLTAGE (11 kV or 33 kV) IN NWFP. DISTRICT BANNU. TEHSIL LAKKI MARWAT.

No.	DESCRIPTION	UNIT	11 kV			33 kV			COST DIFFERENCE (11 kV - 33 kV)	
			QTY	RATE Rs.	COST Rs.(000)	QTY	RATE Rs.	COST Rs.(000)	Rs. (000)	%
5.	SUBSTATION COST (132/11 & 132/33)	MVA	35	1000000	35000	35	800000	28000	7000	20
6.	TRANSMISSION LINE COST (132 kV)	Km	44	1050000	46200	33	1050000	34650	11550	25
	Total Capital Cost				156551			126653	29898	19
7.	ENERGY LOSSES	kWH	2067515	2	4135	210125	2	420	3715	90
8.	PRESENT WORTH OF COSTS									
	1.Energy Losses	Rs.(000)			27567			2800	24767	90
	2. Capital (Including O & M)	Rs.(000)			208213			168448	39765	19
	Total				235780			171248	64532	27

File Name: TABLE6-6.wk1 F / 662

TABLE T6-7

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL TUBEWELL (10 HP)

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL
A.	BASIC DATA					
1.	Life	Yrs	7	20	12	30
2.	Engine/Motor Size	HP	12	10	10	10
3.	Size of PV Array	kW	-	7.5	-	-
4.	Generator Size	kW	-	-	8.8	6.1
5.	Energy Requirement/Output	kWh	7460	7460	7460	7460
B.	CAPITAL COST					
1.	Engine/Motor	Rs	8000	6600	6600	6600
2.	PV Array/Wind Generator/ Central Grid Generation	Rs.	-	1035000	298135	164700
Total			8000	1041600	304735	171300
C.	OPERATING EXPENSES					
1.	O & M Cost	Rs.	5015	0	15237	8565
2.	Fuel/Energy Cost	Rs.	17927	0	0	0
Total			22942	0	15237	8565
D.	TOTAL ANNUAL COSTS					
1.	Annualized Capital Cost	Rs.	1643	122346	44724	18171
2.	Operating Cost	Rs.	22942	0	15237	8565
Total		Rs.	24585	122346	59961	26736
Cost/kWh Delivered		Rs.	3.30	16.40	8.04	3.58

TUBEWELL HP	10 HP
EFF. FOR WIND GEN	0.85 %
DIESEL ENG. EFF	0.175 pu
DIESEL CONSUMPTION	350 gm/BHP/Hr
CF AT CUSTOMER	0.8125
LOAD FACTOR	1000 Hrs
COSTS:	
- DIESEL GENERATOR	8257 RS/KW
- WIND GENERATOR	33879 RS/KW
- PV ARRAY	138000 RS/KW
- BATTERY FOR PV	3440 RS/KWH
- MICRO HYDEL	27000 RS/KW
- GENE./TRANS/DIST	30000 RS/KW
- DIESEL/LITRE	3.5 RS/LITRE
- ENGINE OIL/LITRE	9 RS/LITRE
- ELECTRICITY	0.61 RS/KWH
O&M	
- DIESEL	0.2 pu
- WIND	0.05 pu
- MICRO HYDEL	0.05 pu
- CENTRAL GRID	300 Rs./kW
DIESEL COMSUMPTION	5122
DF	0.1 pu

FILENAME : TABT6-7.WK1 F / 42 ASA

TABLE T5-5

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL VILLAGE IN PUNJAB

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A	BASIC DATA						
1.	Life	Yr	7	20	12	30	30
2.	Generator Size	kW	187	-	178	155	112
3.	PV Array Size	kW	-	178	-	-	-
4.	Battery Size	kWh	-	1068.00	-	-	-
5.	Energy Output	MWh	264	264	264	264	264
B.	CAPITAL COST						
1.	PV Array/Generator/ Central Grid Generation	Rs	897600	24564000	4574600	4185000	3708000
2.	Inverter/Battery	Rs.	0	3673920	0	0	0
Total			897600	28237920	4574600	4185000	3708000
C.	OPERATING EXPENSES						
1.	O & M Cost	Rs.	179520	183696	228730	209250	165400
2.	Lube Oil	Rs	109347	0	0	0	0
3.	Fuel/Energy Cost	Rs.	574074	0	0	0	161040
Total			862941	183696	228730	209250	346440
D.	TOTAL ANNUAL COSTS						
1.	Annualized Capital Cost	Rs.	184367	3317956	671551	444029	393419
2.	Operating Cost	Rs.	862941	183696	228730	209250	346440
Total			1047308	3501652	900281	653279	739859
Cost/kWh Delivered			3.97	13.26	3.41	2.47	2.80

- Population	No	
- Number of households	No	
- Number of Customers		
a. Domestic	No.	
b. Community	No.	
c. Commercial	No	
d. Small Industry	No.	
e. Tubewell for Water Supply	No.	
f. Street Lighting	No.	
- Energy Consumption	MWh	26
- Maximum Demand	kW	
- Load Factor	pu	

TABLE T6-8

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL VILLAGE IN PUNJAB

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF FOR WIND GEN	0.85 %					
	DIESEL ENG BASE EFF	0.175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0.76470					
	LOAD FACTOR	1752 Hrs					
	LENGTH OF DIST. LINE	3 KM					
	COSTS:						
	- DIESEL GENERATOR	4800 RS/KW					
	- WIND GENERATOR	25700 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE./TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3.5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0.61 RS/KWH					
	- DISTRIBUTION LINE	56000 RS/KM					
	O&M						
	- DIESEL	0.2 pu					
	- WIND	0.05 pu					
	- MICRO HYDEL	0.05 pu					
	- CENTRAL GRID	0.05 pu					
	DIESEL COMSUMPTION	164021 LITRES					
	DF	0.1 pu					

FILENAME : TABT6-8.WK1 F / 42 ASA

TABLE T6-9

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL VILLAGE IN SINDH

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A	BASIC DATA						
1	Life	Yr	7	20	12	30	30
2	Generator Size	kW	172	-	164	142	105
3	PV Array Size	kW	-	164	-	-	-
4	Battery Size	kWh	-	984.00	-	-	-
5.	Energy Output	MWh	206	206	206	206	206
B	CAPITAL COST						
1.	PV Array/Generator/ Central Grid Generation	Rs.	860000	22632000	4214800	3834000	3438000
2	Invertor/Battery	Rs.	0	3384960	0	0	0
Total			860000	26016960	4214800	3834000	3438000
C	OPERATING EXPENSES						
1	O & M Cost	Rs.	172000	169248	210740	191700	171900
2.	Lube Oil	Rs.	85478	0	0	0	0
3	Fuel/Energy Cost	Rs.	448760	0	0	0	125660
Total			706238	169248	210740	191700	297560
D	TOTAL ANNUAL COSTS						
1.	Annualized Capital Cost	Rs.	176644	3056993	618733	406787	364772
2.	Operating Cost	Rs.	706238	169248	210740	191700	297560
Total			882882	3226241	829473	598487	662332
Cost/kWh Delivered			4.29	15.66	4.03	2.91	3.22

- Population		No
- Number of households		No
- Number of Customers		
	a. Domestic	No.
	b. Community	No.
	c. Commercial	No.
	d. Small Industry	No.
	e. Tubewell for Water Supply	No.
	f. Street Lighting	No.
- Energy Consumption		MWh
- Maximum Demand		kW
- Load Factor		pu

FILENAME : TABT6-9.WK1 F / 42 ASA

TABLE T6-9

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL VILLAGE IN SIND

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF. FOR WIND GEN	0.85 %					
	DIESEL ENG. BASE EFF.	0 175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0.76470					
	LOAD FACTOR	1489 Hrs					
	LENGTH OF DIST LINE	3 KM					
	COSTS:						
	- DIESEL GENERATOR	5000 RS/KW					
	- WIND GENERATOR	25700 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE /TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3.5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0.61 RS/KWH					
	- DISTRIBUTION LINES	56000 RS/KM					
	O&M						
	- DIESEL	0.2 pu					
	- WIND	0.05 pu					
	- MICRO HYDEL	0.05 pu					
	- CENTRAL GRID	0.05 pu					
	DIESEL COMSUMPTION	128217 LITRES					
	DF	0.1 pu					

TABLE T6-10

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL VILLAGE IN NWFP

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A.	BASIC DATA						
1.	Life	Yr	7	20	12	30	30
2.	Generator Size	kW	152	-	145	126	96
3.	PV Array Size	kW	-	145	-	-	-
4.	Battery Size	kWh	-	870.00	-	-	-
5.	Energy Output	MWh	269	269	269	269	269
B.	CAPITAL COST						
1.	PV Array/Generator/ Central Grid Generation	Rs	760000	20010000	3726500	3402000	3048000
2.	Invertor/Battery	Rs	0	2992800	0	0	0
Total			760000	23002800	3726500	3402000	3048000
C.	OPERATING EXPENSES						
1.	O & M Cost	Rs	152000	149640	186325	170100	152400
2.	Lube Oil	Rs	111101	0	0	0	0
3.	Fuel/Energy Cost	Rs	583282	0	0	0	164090
Total			846383	149640	186325	170100	316490
D.	TOTAL ANNUAL COSTS						
1.	Annualized Capital Cost	Rs	156104	2702829	547050	360952	323393
2.	Operating Cost	Rs	846383	149640	186325	170100	316490
Total			1002487	2852469	733375	531052	639883
Cost/kWh Delivered			3.73	10.60	2.73	1.97	2.38

- Population
- Number of Households
- Number of Customers
  - a. Domestic
  - b. Community
  - c. Commercial
  - d. Small Industry
  - e. Tubewell for Water Supply
  - f. Street Lighting
- Energy Consumption
- Maximum Demand
- Load Factor

FILENAME : TART6-10 WK1 F / 47 ASA

TABLE T6-10

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL VILLAGE IN NWFP.

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF. FOR WIND GEN	0.85 %					
	DIESEL ENG. BASE EFF	0.175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0.76470					
	LOAD FACTOR	2190 Hrs					
	DISTRIBUTION LINE	3 KM					
	COSTS:						
	- DIESEL GENERATOR	5000 RS/KW					
	- WIND GENERATOR	25700 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE /TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3.5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0.61 RS/KWH					
	- DISTRIBUTION LINE	56000 RS/KM					
	O&M						
	- DIESEL	0.2 pu					
	- WIND	0.05 pu					
	- MICRO HYDEL	0.05 pu					
	- CENTRAL GRID	0.05 pu					
	DIESEL COMSUMPTION	166652 LITRES					
	OF	0.1 pu					

FILENAME : TABT6-10.WK1 F / 42 ASA

TABLE T6-11

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL VILLAGE IN BALUCHISTAN

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	CENTRAL GRID
A	BASIC DATA					
1	Life	Yr	7	20	12	30
2	Generator Size	kW	26	-	25	16
3	PV Array Size	kW	-	25	-	-
4	Battery Size	kWh	-	150.00	-	-
5	Energy Output	MWh	33	33	33	33
B	CAPITAL COST					
1	PV Array/Generator/ Central Grid Generation	Rs	364000	3450000	675000	912000
2	Invertor/Battery	Rs	0	516000	0	0
Total			364000	3966000	675000	912000
C	OPERATING EXPENSES					
1	O & M Cost	Rs	72800	25800	33750	45600
2	Lube Oil	Rs.	13763	0	0	0
3	Fuel/Energy Cost	Rs.	72254	0	0	20130
Total			158817	25800	33750	65730
D	TOTAL ANNUAL COSTS					
1	Annualized Capital Cost	Rs	74766	466005	99090	96763
2	Operating Cost	Rs.	158817	25800	33750	65730
Total			233583	491805	132840	162493
Cost/kWh Delivered			7.08	14.90	4.03	4.92

-	Population	No	529
-	Number of Households	No.	73
-	Number of Customers		
	a. Domestic	No.	51
	b. Community	No.	1
	c. Commercial	No.	6
	d. Small Industry	No.	0
	e. Tubewell for Water Supply	No.	0
	f. Street Lighting	No.	
-	Energy Consumption	MWh	33.2
-	Maximum Demand	kW	2
-	Load Factor	pu	0.18

FILENAME : TABT6-11 WK1 F / 42 ASA

TABLE T6-11

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL VILLAGE IN BALUCHISTAN

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	CENTRAL GRID
	PARAMETERS					
	TUBEWELL HP	10 HP				
	EFF FOR WIND GEN	0 85 %				
	DIESEL ENG BASE EFF	0 175 pu				
	DIESEL CONSUMPTION	350 gm/BHP/Hr				
	CF AT CUSTOMER	0 76470				
	LOAD FACTOR	1596 Hrs				
	LENGTH OF DIST LINE	5 KM				
	COSTS:					
	- DIESEL GENERATOR	14000 RS/KW				
	- WIND GENERATOR	27000 RS/KW				
	- PV ARRAY	138000 RS/KW				
	- BATTERY FOR PV	3440 RS/KWH				
	- MICRO HYDEL	27000 RS/KW				
	- GENE./TRANS/DIST	36000 RS/KW				
	- DIESEL/LITRE	3 5 RS/LITRE				
	- ENGINE OIL/LITRE	8 RS/LITRE				
	- ELECTRICITY	0 61 RS/KWH				
	- DISTRIBUTION LINE	56000 RS/KM				
	O&M					
	- DIESEL	0 2 pu				
	- WIND	0 05 pu				
	- MICRO HYDEL	0 05 pu				
	- CENTRAL GRID	0 05 pu				
	DIESEL COMSUMPTION	20644 LITRES				
	OF	0 1 pu				

FILENAME : TABT6-11.WK1 F / 42 ASA

TABLE T6-12

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL RURAL AREA IN PUNJAB

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A	BASIC DATA						
1	Life	Yr	7	20	12	30	30
2	Generator Size	kW	37502	-	35716	31118	23796
3	PV Array Size	kW	-	35716	-	-	-
4	Battery Size	kWh	-	214296.00	-	-	-
5	Energy Output	mwh	66485	66485	66485	66485	66485
B	CAPITAL COST						
1	PV Array/Generator/ Central Grid Generation	Rs	157508400	4928808000	910758000	840186000	713880000
2	Invertor/Battery	Rs	0	737178240	0	0	0
Total			157508400	5665986240	910758000	840186000	713880000
C	OPERATING EXPENSES						
1	O & M Cost	Rs	31501680	36858912	45537900	42009300	35694000
2	Lube Oil	Rs	27411367	0	0	0	0
3	Fuel/Energy Cost	Rs	143909679	0	0	0	40555850
Total			202822726	36858912	45537900	42009300	76249850
D	TOTAL ANNUAL COSTS						
1	Annualized Capital Cost	Rs	32352225	665753383	133699274	89143735	75742668
2	Operating Cost	Rs	202822726	36858912	45537900	42009300	76249850
Total			235174951	702612295	179237174	131153035	151992518
Cost/kWh Delivered			3.54	10.57	2.70	1.97	2.29

- Population
- Number of House
- Number of Custo
  - a. Domestic
  - b. Community
  - c. Commercial
  - d. Small Indust
  - e. Tubewell for Supply
  - f. Street Light
- Energy Consumpt
- Maximum Demand
- Load Factor

FILENAME : TABT6-12 WK1 F / 42 ASA

TABLE T6-12

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL RURAL AREA IN PUNJAB

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF FOR WIND GEN	0 85 %					
	DIESEL ENG BASE EFF	0 175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0 76470					
	LOAD FACTOR	2190 Hrs					
	COSTS:						
	- DIESEL GENERATOR	4200 RS/KW					
	- WIND GENERATOR	25500 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE /TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3 5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0 61 RS/KWH					
	O&M						
	- DIESEL	0 2 pu					
	- WIND	0 05 pu					
	- MICRO HYDEL	0 05 pu					
	- CENTRAL GRID	0 05 pu					
	DIESEL CONSUMPTION	4E+07 LITRES					
	DF	0 1 pu					

FILENAME : TABT6-12.WK1 F / 42 ASA

TABLE T6-13

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL RURAL AREA IN SIND

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A	BASIC DATA						
1	Life	Yr	7	20	12	30	30
2	Generator Size	kW	14275	-	13595	11845	9058
3	PV Array Size	kW	-	13595	-	-	-
4	Battery Size	kWh	-	81570.00	-	-	-
5	Energy Output	MWh	21259	21259	21259	21259	21259
B	CAPITAL COST						
1	PV Array/Generator/ Central Grid Generation	Rs	53355000	1876110000	346672500	319815000	271740000
2	Inverter/Battery	Rs	0	280600800	0	0	0
Total			53355000	2156710800	346672500	319815000	271740000
C	OPERATING EXPENSES						
1	O & M Cost	Rs	11991000	14030040	17333625	15990750	13587000
2	Lube Oil	Rs	8766497	0	0	0	0
3	Fuel/Energy Cost	Rs	46024111	0	0	0	12967990
Total			66781608	14030040	17333625	15990750	26554990
D	TOTAL ANNUAL COSTS						
1.	Annualized Capital Cost	Rs.	12314757	253413519	50891523	33932372	28831614
2.	Operating Cost	Rs.	66781608	14030040	17333625	15990750	26554990
Total			79096365	267443559	68225148	49923122	55386604
Cost/kWh Delivered			3.72	12.58	3.21	2.35	2.61

- Population	No	26
- Number of Households	No.	3
- Number of Customers		
a. Domestic	No.	2
b. Community	No.	
c. Commercial	No	
d. Small Industry	No	
e. Tubewell for Water Supply	No	
f. Street Lighting	No	
- Energy Consumption	MWh	2125
- Maximum Demand	kW	1
- Load Factor	pu	

FILENAME : TABT6-13 W1 F / 42 ASA

TABLE T6-13

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL RURAL AREA IN SIND

No.	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF. FOR WIND GEN	0 95 %					
	DIESEL ENG. BASE EFF	0 175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0 76470					
	LOAD FACTOR	1840 Hrs					
	COSTS:						
	- DIESEL GENERATOR	4200 RS/KW					
	- WIND GENERATOR	25500 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE./TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3 5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0 61 RS/KWH					
	O&M						
	- DIESEL	0 2 pu					
	- WIND	0 05 pu					
	- MICRO HYDEL	0 05 pu					
	- CENTRAL GRID	0 05 pu					
	DIESEL COMSUMPTION	1E+07 LITRES					
	DF	0 1 pu					

FILENAME : TABT6-13.WK1 F / 42 ASA

TABLE T6-14

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL RURAL AREA IN NWFP

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
A	BASIC DATA						
1	Life	Yr	7	20	12	30	30
2	Generator Size	kW	18396	-	17520	15264	11673
3	PV Array Size	kW	-	17520	-	-	-
4	Battery Size	kWh	-	105120 00	-	-	-
5	Energy Output	MWh	40440	40440	40440	40440	40440
B	CAPITAL COST						
1	PV Array/Generator/ Central Grid Generation	Rs	77263200	2417760000	446760000	412128000	350190000
2	Inverter/Battery	Rs	0	361612800	0	0	0
Total			77263200	2779372800	446760000	412128000	350190000
C	OPERATING EXPENSES						
1	O & M Cost	Rs	15452640	18080640	22338000	20606400	17509500
2	Lube Oil	Rs	16675748	0	0	0	0
3	Fuel/Energy Cost	Rs	87547677	0	0	0	24668400
Total			119676065	16060640	22338000	20606400	42177900
D	TOTAL ANNUAL COSTS						
1	Annualized Capital Cost	Rs.	15809661	326576304	65584368	43726781	37155159
2	Operating Cost	Rs.	119676065	18060640	22338000	20606400	42177900
Total			135545920	344656944	87922368	64333181	79333059
Cost/kWh Delivered			3 35	8 52	2 17	1 59	1 96

- Population No
- Number of Households No
- Number of Customers
  - a Domestic No
  - b Community No
  - c Commercial No
  - d Small Industry No
  - e Tubewell for Water Supply No
  - f Street Lighting No
- Energy Consumption M
- Maximum Demand k
- Load Factor P

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TABLE T6-14

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION
OF A TYPICAL RURAL AREA IN NWFP

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	MICRO HYDEL	CENTRAL GRID
	PARAMETERS						
	TUBEWELL HP	10 HP					
	EFF. FOR WIND GEN	0.85 %					
	DIESEL ENG. BASE EFF	0 175 pu					
	DIESEL CONSUMPTION	350 gm/BHP/Hr					
	CF AT CUSTOMER	0 76470					
	LOAD FACTOR	2716 Hrs					
	COSTS:						
	- DIESEL GENERATOR	4200 RS/KW					
	- WIND GENERATOR	25500 RS/KW					
	- PV ARRAY	138000 RS/KW					
	- BATTERY FOR PV	3440 RS/KWH					
	- MICRO HYDEL	27000 RS/KW					
	- GENE./TRANS/DIST	30000 RS/KW					
	- DIESEL/LITRE	3.5 RS/LITRE					
	- ENGINE OIL/LITRE	8 RS/LITRE					
	- ELECTRICITY	0 61 RS/KWH					
	O&M						
	- DIESEL	0 2 pu					
	- WIND	0 05 pu					
	- MICRO HYDEL	0 05 pu					
	- CENTRAL GRID	0 05 pu					
	DIESEL COMSUMPTION	3E+07 LITRES					
	DF	0.1 pu					

FILENAME : TABT6-14.WK1 F / 42 ASA

TABLE T6-15

CASE STUDY FOR TECHNICAL ANALYSIS

DECENTRALIZED GENERATION OPTIONS FOR ELECTRIFICATION OF A TYPICAL RURAL AREA IN BALUCHISTAN

No	DESCRIPTION	UNIT	DIESEL	SOLAR	WIND	CENTRAL GRID
A	BASIC DATA					
1	Life	Yr	7	20	12	30
2	Generator Size	kW	2035	-	1938	1291
3	PV Array Size	kW	-	1938	-	-
4	Battery Size	kWh	-	11628.00	-	-
5	Energy Output	MWh	3319	3319	3319	3319
B	CAPITAL COST					
1	PV Array/Generator/ Central Grid Generation	Rs	8547000	267444000	49419000	46476000
2	Inverter/Battery	Rs	0	40000320	0	0
Total			8547000	307444320	49419000	46476000
C	OPERATING EXPENSES					
1	O & M Cost	Rs	1709400	2000016	2470950	2323800
2	Lube Oil	Rs	1368585	0	0	0
3	Fuel/Energy Cost	Rs	7185070	0	0	2024590
Total			10263055	2000016	2470950	4348390
D	TOTAL ANNUAL COSTS					
1	Annualized Capital Cost	Rs	1755554	36124708	7254709	4931104
2	Operating Cost	Rs	10263055	2000016	2470950	4348390
Total			12018609	38124724	9725659	9279494
Cost/kWh Delivered			3.62	11.49	2.93	2.80

- Population		No	41860
- Number of Households		No	6174
- Number of Customers			
	a Domestic	No	4322
	b Community	No	100
	c Commercial	No	431
	d Small Industry	No	20
	e Tubewell for Water Supply	No	0
	f Street Lighting	No	216
- Energy Consumption		MWh	3318.72
- Maximum Demand		kW	1647
- Load Factor		PU	0.23

FILENAME : TABT6-11 WK1 F / 42 ASA