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# EVALUATION OF AID PROJECT NO. 527-0226

# FOR THE

# DEVELOPMENT OF SMALL HYDROELECTRIC POWER PLANTS

Prepared for the

Agency for International Development (AID)

and the

Empresa Pública de Electricidad del Perú (ELECTROPERU)

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# PREFACE

A Spanish language draft of this report was submitted to AID and ELECTROPERU at the end of October 1986, requesting observations and comments. Once the comments were received, the text was reviewed and modified to include adjustments which, in the opinion of the consulting mission, were justified. The opportunity was also used to add to the report a significant amount of information that was received after the first draft had been submitted.

The present document in English is a translation of the final Spanish language version of the report.

The members of the evaluation team would like to express their appreciation to the personnel of the AID Project Office and other ELECTROPERU offices, as well as to the AID personnel connected to the Project, for the cooperation and help which was received.

## DEFINITIONS

| | |
|---|---|
| AID | Agency for International Development |
| BANVIP | Peruvian Housing Bank (Banco de la Vivienda del Perú) |
| CESPAC | Center of Audiovisual Teaching and Training Services (Centro de Servicios de Pedagogía Audiovisual para la Capacitación) |
| COMMSA | Consultores Mineros Metalúrgicos S.A. |
| EFET | ELECTROLIMA Electrotechnical Training School (Escuela de Formación Electrotécnica de ELECTROLIMA) |
| ELECTROPERU | Public Electricity Company of Peru (Empresa Pública de Electricidad del Perú S.A.) |
| EPS | Electricity Promotion Service of the Rural Electrification Department of ELECTROPERU |
| EPU | Electrification Project Unit (or Units) |
| ETEMHI | ELECTROLIMA Mechanics and Hydraulics Technical School (Escuela Técnica de Mecánica e Hidráulica de ELECTROLIMA) |
| GOP | Government of Peru |
| HIDRANDINA | Regional Electric Company Electro Norte Medio HIDRANDINA S.A. |
| IDB | Interamerican Development Bank |
| MEM | Ministry of Energy and Mines |
| NRECA | National Rural Electric Cooperative Association |
| ONERN | National Office for the Evaluation of Natural Resources (Oficina Nacional de Evaluación de Recursos Naturales) |
| OPAT | Office of the Program for Applied Technology |
| PACD | Project Assistance Completion Date |
| REC | Regional Electric Company (or Companies) |
| RULCOP | Unified Regulations for Bidding and Contracting of Public Works |
| SHPP | Small Hydroelectric Power Plants |

"Gerencias" of ELECTROPERU are referred to as Divisions and "Sub-Gerencias" are referred to as Departments.

In all numbers, a period is used to separate decimals and a comma to separate thousands and millions.

| | |
|---|---|
| I/. | - inti |
| US$ | - United States dollars (US$1 - I/. 17.50) |
| L | - pounds sterling (L 1.00 - I/. 20.15) |
| kW | - 1,000 watts |
| MW | - 1,000 kW |
| kV | - 1,000 volts |

micro-hydro power plants - capacity up to 100 kW
mini-hydro power plants - capacity between 100 kW and 1000 kW
small hydroelectric power plants - capacity less than 10,000 kW

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# 1. SUMMARY

## 1.1 Project Objectives

The, main purpose of the Small Hydroelectric Plants Project has been the strengthening of an institutional base in Peru capable of supplying hydro-generated electric power at reasonable costs to rural towns in the sierra and high jungle regions.

More specifically, the technical assistance and training activities have focused on formulating a methodology for the technical and economic evaluation and selection of projects, the preparation of feasibility studies, the training of personnel, and the implementation of suitable procedures for the operation and maintenance of the SHPP, as well as the development of a program for promoting the productive and rational utilization of electric power in the rural areas covered by the Project. The purpose of the Project has been not just to build the electrical facilities but also to endow ELECTROPERU with qualified personnel and suitable procedures for successfully carrying out similar projects in the future.

The Project Agreement was signed in November 1980, with AID providing a Loan of US$9.0 million and a Grant of up to US$1.0 million. Based on the rate of utilization of Grant funds, the maximum amount of the latter contribution has been set at US$750,000. The Government of Peru (GOP) agreed to contribute the equivalent of US$4.4 million to the Project. This contribution was increased to US$6.36 million in May 1985.

To the date of this report, three of the ten SHPP included in the Project have been put into operation. The Project Assistance Completion Date (PACD) has been set at May 19, 1987.

## 1.2 Objectives of the Evaluation

The objectives of the project evaluation, as set forth by AID, are as follows:

- Ascertain the progress achieved in each Project task and sub-program, and recommend actions needed to improve and expedite project execution.

- Analyze the institutionalization in ELECTROPERU of the Small Hydroelectric Plant Program, and determine ELECTROPERU's capacity to carry out other projects similar to the AID-financed project in the future.

- Review cost-benefit analyses and socioeconomic studies of SHPP, compare the benefits expected from the SHPP with those of ongoing and proposed larger power projects, and determine the relative economic and social rate of return for the smaller projects and the priority for future financing that should be assigned to them.

- Review the methodology used in preparing and evaluating the sub-projects and recommend any appropriate improvements.

- Examine ELECTROPERU's Project Implementation Plan to determine whether all project activities can be completed prior to the PACD.

- Provide a detailed analysis of the Project's successes and failures.

## 1.3 Methodology Employed in the Evaluation

In accordance with the scope of the evaluation as specified in the terms of reference, the required work has been completed through the following general activities:

- interviews of personnel of ELECTROPERU, AID, the Ministry of Energy and Mines (MEM), and other organizations involved with the Project and with the country's electrification efforts, as well as beneficiaries of the SHPP;

- visits to the regions and sites of two sub-projects which are still underway and two which have already been completed;

- examination and analysis of progress reports, prefeasibility and feasibility studies, drawings, contracts and other pertinent documents; and

- comparison of the completed sub-projects and their verifiable results with the designs and forecasts presented in the corresponding studies.

The fact that to date only three of the SHPP included in the Project have been completed, combined with the limited time that these have been operational, has substantially limited the possibility of comparing actual and projected costs and benefits.

## 1.4 Progress Achieved by ELECTROPERU

ELECTROPERU initially assigned the responsibility for carrying out the Project to the Office of the Program for Applied Technology (OPAT), which was later replaced by the Office of Hydrogeneration of the Rural Electrification Division. Towards the end of 1985, this Division became a Department within the Construction Division.

The AID Project Office is established within the Rural Electrification Department and is charged with direct implementation of the Project, supported by the regional Electrification Project Units (EPU), which are in charge of supervising and directing the construction of the sub-projects. Once the facilities are completed and the plants are operational, they are transferred to the Regional Electric Companies (REC), which are in charge of managing, operating and maintaining them.



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Implementation of the technical assistance portion of the Project is another responsibility of the Rural Electrification Department, in coordination with the EPU and the REC.

Initially, the Project was intended to finance the construction of 28 power plants in the 100-1,000 kW range. Once the prefeasibility studies were completed, 15 sub-projects were selected for final feasibility studies.

Of these 15 sub-projects, ten were selected for construction, in keeping with the limits imposed by the funds available from the AID Loan and ELECTROPERU's contribution. To date, three sub-projects have been completed and are in service. The remaining seven are still under construction. Some of these have suffered significant delays in their implementation.

ELECTROPERU has not shown the same interest in the technical assistance as it has evidenced in the preparation and construction of the power plants. Specifically, technical assistance offered in promoting the productive use of electric power and in maintaining the SHPP has not been used. Both of these activities are of great importance to the success of rural electrification projects.

There is little time left for contracting foreign technical assistance prior to the PACD. However, one of the country's Regional Electric Companies, ELECTROLIMA, does have a technical school which could be used, in combination with other measures, to train operations and maintenance personnel for the SHPP.

To date, ELECTROPERU's promotional work has concentrated primarily on the residential uses of electricity, apparently quite successfully. On the other hand, ELECTROPERU has not given much attention to promoting the productive uses of electric power, although the recently created Electricity Promotion Service in ELECTROPERU would be able to make use of technical assistance in this field.

ELECTROPERU now has a group of professionals trained in the preparation, evaluation and execution of small hydroelectric power plant projects. Moreover, the sub-project evaluation methodology, known in ELECTROPERU as the "AID Methodology", will be used in the evaluation of future SHPP projects.

## 1.5 Prospects for Attaining Goals

Given the rate of work to date and the problems observed during site visits to two sub-projects, it will be difficult to complete the seven SHPP still under construction prior to the PACD. The onset of the rainy season will cause further delays.

In order to complete the sub-projects in a timely manner, certain extraordinary measures will need to be taken. These include supplying site

inspectors with radios and vehicles and accelerating the contractors' work.

Although little time is left to meet the original goals for promotion of the productive use of electric power and the maintenance of the SHPP, some progress could still be achieved in these areas if certain measures aimed at providing technical assistance are implemented immediately (see Section 1.9). If there is insufficient time prior to the PACD to contract foreign experts, qualified assistance could be sought domestically.

## 1.6 Future Development of Small Hydroelectric Power Plants

ELECTROPERU's recent experience in rural electrification based on small hydroelectric power plants can be summarized as follows: since 1980, 36 power plants have been built, including three AID Project plants; 92 other plants (including seven from the Project) are in different stages of study and execution; and several packages including a total of approximately 90 power plant projects are being evaluated.

When the problems encountered in the past have been corrected, ELECTROPERU will be fully capable of executing other similar projects.

The SHPP play an important role in rural electrification, which has been assigned a high priority in the government's overall development program. The SHPP are particularly useful in bringing electric power to communities located far from the existing interconnected plants and grids.

When compared with the other possible sources of electric power, SHPP can supply electricity to isolated rural areas at reasonable costs. The SHPP projects are relatively easy to carry out, facilitating their implementation by the Regional Electric Companies and contributing in this way to the goal of national decentralization. Their reduced size allows for rapid implementation and delivery of their benefits, in accordance with the country's ability to finance them, without requiring users to await the lengthy erection of a major facility. The SHPP also take advantage of renewable natural resources and reduce the country's dependence on petroleum, which are also important goals of the Government.

## 1.7 Summary of Project Successes

Despite the delays the Project has encountered, some of which are attributable to its implementation during a period of restructuring and decentralization of ELECTROPERU and the Regional Electric Companies, several significant successes have been achieved:

a) Ten small hydroelectric plants and their associated distribution networks will have been built, at reasonable costs and within reasonable time periods, permitting the delivery of electricity to some 18,000 families in rural areas of the country.



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b) The development of a national private industry capable of manufacturing electromechanical and electrical equipment for SHPP has been stimulated and supported, which should reduce the costs of future projects.

c) ELECTROPERU's staff has been trained in the preparation, evaluation and implementation of SHPP projects. However, there is some danger that the experience gained could be lost as discussed in Section 1.9.

d) A methodology for the economic evaluation of SHPP projects has been implanted in ELECTROPERU.

e) As a result of the use of the economic evaluation methodology in this Project, sub-projects with adequate economic benefits have been selected and implemented, thus contributing to the rational use of the country's resources.

f) The interest of rural residents in furthering the development of rural electrification with the help of ELECTROPERU has been verified and encouraged, as has their desire to contribute toward the betterment of their own standard of living.

Through the construction of the SHPP, the Project has contributed significantly to achieving an important government objective, the improvement of the standard of living in rural areas of the country. For this reason, it is considered that the Project has been well focused and has fulfilled its primary purpose.

## 1.8 Summary of Shortcomings Requiring Immediate Attention

Although the Project has achieved some degree of success in the construction of the SHPP, there are still some problems and failures that could delay the completion of the sub-projects. Following is a summary of those problems, together with recommendations for overcoming them.

a) Very little effort has been dedicated to promoting the productive use of electricity. The training in this area that was called for in the Project Agreement has not taken place.

   Recommendation: Contract an expert in rural development for approximately four months to train and work with personnel of ELECTROPERU's recently created Electricity Promotion Service, assisting them in implementing several measures designed to promote the productive use of electric power among residents of Project service areas

b) Attention has not been given to training personnel of the Regional Electric Companies to operate and maintain the SHPP. The technical assistance that had been foreseen for this purpose has not been used.

   Recommendation: In collaboration with ELECTROLIMA, use ELECTROLIMA's technical schools to train personnel of the Regional Electric

Companies in the operation and maintenance of the SHPP. In the short term, and using available Grant funds, bring in experts from the manufacturers of the new electromechanical equipment for short periods of time to train the school's instructors; purchase certain new equipment to supplement existing equipment in the schools; and send unemployed graduates of the schools to the Regional Electric Companies either to accept permanent jobs or to provide on-the-job training to the SHPP operators.

c) The efficiency of the work of the on-site construction inspectors suffers greatly because of a lack of means of communication and transportation.

Recommendation: Acquire radio equipment to allow for immediate and direct communications between on-site inspectors and the offices of the Electrification Project Units (or the Regional Electric Companies). Likewise, rent or purchase vehicles for the inspectors' use until construction has been completed.

d) The construction of several of the sub-projects has been delayed as a result of the slow procedures used to resolve contractor claims.

Recommendation: Take extraordinary measures to accelerate the analysis of claims for extra work and the approval and payment of the corresponding amounts, resorting to solutions such as the following:

- contracting the additional personnel required in the Project Office;
- providing mobility to Project Office personnel;
- establishing special procedures that would permit the approval of payments for additional work without having to resort to the General Manager or the Directors of ELECTROPERU; and/or
- paying advances in anticipation of the approval of the additional sums in question.

e) The slow progress being achieved in some of the sub-projects will not permit their completion prior to the PACD (May 19, 1987).

Recommendation: In special cases, consider supplementing the work of the contractors who are furthest behind with work administered under force account. Require the contractors to increase their personnel, equipment and working hours and to keep their work plans up to date.

f) The transfer of the Electrification Project Units to the Regional Electric Companies, which is currently in progress, could lead to delays in the supervision of the sub-projects and in the approval and disbursement of payments to the contractors.

Recommendation: Seek a way to avoid changing the personnel and procedures that are already established in the Electrification

Project Units for supervising and controlling sub-projects and handling Project funds during the remainder of the Project's life.

g) Project funds have not been handled expeditiously. A current balance of approximately US$900,000 has been disbursed by AID but has not yet been accounted for by ELECTROPERU.

Recommendation: Expedite the final accounting for completed projects, the payment of pending invoices and the updating of the corresponding accounting records.

## 1.9 Summary of Problems with Longer Term Solutions

In addition to the problems requiring immediate attention, several problems and situations that have made the preparation and implementation of SHPP projects difficult have been identified within ELECTROPERU. The correction of the deficient situations could facilitate the implementation of future projects and agreements, as well as the improvement of ELECTROPERU's future endeavors. The primary problems and the recommended solutions are the following:

a) ELECTROPERU has inadequately supervised the preparation of studies and designs by the consulting firms.

Recommendation: Implement a stricter supervision of the consulting firms in the future, especially with regard to obtaining and using field information, design concepts and standardization, and the identification of potential construction problems.

b) The consulting firms generally prepared their studies and designs at a level of detail which is not justified given the usually scant and unreliable basic data. Likewise, the designs are unnecessarily complex and lack uniformity.

Recommendation: Strive for simple and flexible designs, using standardized designs whenever possible.

c) The lump sum construction contracts are drafted and interpreted too rigidly, which hinders the adjustments which are inevitable in projects of this type.

Recommendation: Make contracts more flexible, emphasizing fixed unit costs and flexible quantities, always under the control of the site inspector, so that the contracts can be adapted to the real conditions found at the sites, without the need to resort to so many claims that delay the projects.

d) The tendering, awarding and contracting process is too slow and complex.

Recommendation: Facilitate the process by taking measures such as allowing approval of awards and contracts at lower decision levels

than the present ones. All the procedures of the process, and especially those that relate to the selection of the winning bidder, should be reviewed and revised.

e) Insufficient attention has been given to providing maintenance equipment and tools to the SHPP.

Recommendation: Provide the SHPP with a complete set of the equipment and tools necessary for efficient operation and maintenance, including means of communication (radio or telephone) between the plants and the zonal offices of the Regional Electric Companies.

f) The plants have been observed to operate sometimes at a level that does not take full advantage of the available water flow, for fear that the flow could suddenly fall below the level required to maintain the load.

Recommendation: Install water level monitors in the forebays with the ability to actuate an alarm in the powerhouse if the water level should fall below a specified level.

g) Certain defects in the hydraulic governors at the plants that are already in operation have been noted.

Recommendation: Investigate the advantages of the various types of governors presently available, specify the most advantageous type and arrange for it to be manufactured locally.

h) In general, the SHPP were designed to use a flow of water that would be available 90 percent of the time. However, some of the SHPP will work in conjunction with a thermal plant, while others may be joined to an interconnected grid in future years. In such cases, a greater design capacity might be appropriate.

Recommendation: Consider and evaluate alternatives of greater design flows in cases such as those mentioned above. Also, where the minimum flow rate is specified with great uncertainity, evaluate designs that would facilitate the future expansion of the SHPP at a reasonable cost.

i) There is a risk of losing personnel trained in construction implementation and supervision because of the transfer of the Electrification Project Units to the Regional Electric Companies. There is also a concern about the future of trained personnel in the Project Office once the Project ends.

Recommendation: Take steps to ensure that the Electrification Project Units are transferred as integral units, thereby taking advantage of the existing experience and capabilities. Also take prompt steps to assure skilled personnel in the Project Office that their employment will continue after the Project Agreement expires, and try to keep the staff together in a similar activity. Permanent positions

should be offered to the present contract employees, both in the Electrification Project Units and in the Project Office.

j) Several vacant positions in the Rural Electrification Department especially at the unit head level, interfere with the fulfillment of the duties of this entity.

Recommendation: Assign personnel to the vacant posts, or replace the positions with another with the responsibility of assisting the department manager, in order to achieve a better coordination of efforts and a greater availability of information.

k) Although the selection of the sub-projects implemented under the Project has been based on benefit/cost ratios, that criterion is not applied universally in ELECTROPERU for the selection of projects to be included in the National Plan for Expansion of the Electric Frontier.

Recommendation: Revise the procedure for selecting SHPP projects, making the benefit/cost ratio the primary criterion for assigning priorities. Also review and refine the economic evaluation methodology, using the experience gained to date and the data available from the sub-projects which have already been completed.

# 2. INTRODUCTION

## 2.1 Project Description

The main purpose of the Small Hydroelectric Plants Project has been the strengthening of an institutional base in Peru capable of supplying hydro-generated electric power at reasonable costs to rural towns in the sierra and high jungle regions.

AID funding has included a US$9.0 million Loan for studies, construction and equipping of small hydroelectric power plants (SHPP) generating between 100 and 1000 kW. The Loan covers civil works, generating equipment, and transmission and distribution systems. AID has also provided a Grant of up to US$1.0 million for technical assistance and training, aimed at improving ELECTROPERU's ability to carry out small hydroelectric programs.

More specifically, the technical assistance and training activities have focused on formulating a methodology for the technical and economic evaluation and selection of projects, the preparation of feasibility studies, the training of personnel, and the implementation of suitable procedures for the operation and maintenance of the SHPP, as well as the development of a program for promoting the productive and rational utilization of electric power in the rural areas covered by the Project. The purpose of the Project has been not just to build the electrical facilities but also to endow ELECTROPERU with qualified personnel and suitable procedures for successfully carrying out similar projects in the future.

The Project Agreement was signed in November 1980, with a projected five-year duration. The Government of Peru (GOP) agreed to contribute the equivalent of US$4.4 million to the project. Because of increases in anticipated construction costs, in May 1985 this contribution was increased to US$6.36 million.

Initially, the Project contemplated the construction of up to 28 SHPP with an average capacity of approximately 300 kW. However, prefeasibility studies led to the selection of 15 sub-projects for which final feasibility studies were prepared, namely:

| | | | |
|---|---|---|---|
| Chongos Alto | 1,000 kW | Sucre-Celendin | 1,000 kW |
| Cutervo | 1,200 kW | Sorochuco | 230 kW |
| Cajabamba | 520 kW | Uchiza | 220 kW |
| Pucará | 400 kW | Querocoto | 720 kW |
| Pachiza | 400 kW | Bambamarca | 1,000 kW |
| Namora | 600 kW | Cascas | 730 kW |
| San Marcos | 330 kW | Contumazá | 600 kW |
| Niepos | 1,000 kW | | |



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Of these 15 sub-projects, ten (the first ten listed), with an average capacity of 620 kW, were selected for construction, in keeping with the limits imposed by the funds available from the Loan and ELECTROPERU. To date, the Chongos Alto, Cajabamba and Pucará projects have been completed and are in service. Of the five sub-projects which were studied but not implemented by the Project, several will be carried out by other means; one is presently under construction, and bids for another will be requested shortly. The location of the sub-projects is shown in Appendix 1.

Project execution has proceeded much more slowly than anticipated in the original work schedule. A great deal of time was spent on designing the methodology for the evaluation and selection of sub-projects. As a result, some already-completed studies had to be modified. Once provided with the methodology, some consulting firms fell behind schedule in the preparation of the studies awarded to them. Other factors contributing to the delays included several organizational changes within ELECTROPERU, slow and complex procedures for tendering and contracting the facilities, and problems related to the procurement of equipment and construction services. Construction of the first sub-project began near the end of 1983.

Because of the delays in project activities, the Project Assistance Completion Date (PACD) has been extended twice, the latest target being May 19, 1987. ELECTROPERU hopes to complete the seven sub-projects still underway by that date. However, to meet this goal, several extraordinary measures will have to be taken, as specified in Sections 4.4 and 5.3 of this report.

In order to facilitate the disbursement of the AID-supplied funds prior to the PACD, Loan funds will be concentrated on the civil works and hydroelectric equipment of only seven of the ten sub-projects and on the electrical works of nine sub-projects. The GOP will finance the entire cost of the civil works, hydroelectric equipment and electrical works that do not receive AID funds.

As of the date of this report, AID has disbursed a total of US$6.26 million from Loan funds and US$313,000 from Grant funds. Based on the utilization to date of Grant funds, the maximum amount of the latter contribution has been set at US$750,000. ELECTROPERU direct expenditures, not including the overhead costs of the Electrification Project Units and the central office, have reached approximately US$3 million.

## 2.2 Objectives of the Evaluation

The objectives of the project evaluation, as set forth by AID in the terms of reference, are as follows:

- Ascertain the progress achieved in each Project task and sub-program in relation to the goals specified in the Project Paper, the Project Agreement and the revised Project Implementation Plan, and recommend actions needed to improve and expedite project execution.

- Analyze the institutionalization in ELECTROPERU of the Small Hydroelectric Plant Program, and determine ELECTROPERU's capacity to carry out other projects similar to the AID-financed project in the future.

- Review benefit/cost analyses and socioeconomic studies of SHPP, compare the benefits expected from the SHPP with those of ongoing and proposed larger power projects, and determine the relative economic and social rate of return for the smaller projects and the priority for future financing that should be assigned to them.

- Review the methodology used in preparing and evaluating the sub-projects and recommend any appropriate improvements.

- Examine ELECTROPERU's Project Implementation Plan to determine whether all project activities can be completed prior to the PACD (May 19, 1987).

- Provide a detailed analysis of the Project's successes and failures.

## 2.3 Scope of the Evaluation

The scope of the evaluation of the Project is defined by the following responsibilities of the consulting mission, as specified in the AID terms of reference:

a) Ascertain the progress attained by ELECTROPERU in the implementation of each one of the Project activities, through the following tasks:

   a-1 Studies: Review at least two of the feasibility and final engineering studies developed under the Project (one of them developed by ELECTROPERU's own technical staff and the other one by an external consultant) and present comments and recommendations for simplifying and/or improving the quality of future studies. Review the criteria used by ELECTROPERU for sub-project selection and make comments and recommendations for improving this procedure.

   a-2 Implementation Support for Promotion Campaign: Review the actions taken by ELECTROPERU to promote the use of electricity,



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determine the effects of such actions in the Project communities and make recommendations for improving the promotion campaign.

a-3 Construction: Determine actual construction and procurement progress on all sub-projects and compare actual progress with the targets set forth in the revised Implementation Plan. Visit at least two of the sub-project sites. Determine the effectiveness and problems of constructing civil works via force account as compared with the use of contractors.

a-4 Technical Assistance: Evaluate the effectiveness of the technical assistance provided to date to the Project (by both US and Peruvian advisors), examine the additional technical assistance proposed by ELECTROPERU, and propose any changes to improve the effectiveness of the technical assistance program or accelerate Project implementation during the remaining life of the Project.

a-5 Maintenance: Look into the availability of personnel and facilities, both within and outside of ELECTROPERU, to provide adquate maintenance to small hydroelectric equipment, and recommend the necessary actions to improve the maintenance program.

b) During visits to the Project offices, look into ELECTROPERU's organization and ascertain the amount of support the Small Hydro Program is receiving from senior management and other divisions. Identify problems and recommend actions to resolve those that are affecting Project implementation, taking into account the desire of ELECTROPERU and AID to accelerate the implementation of the Project.

c) Direct special attention to analyzing the procurement and contracting delays that have been encountered in the Project and to recommending ways in which these problems can be overcome in the future.

d) Given the management capacity and resources currently available within the Project, carefully analyze the revised Project Implementation Plan (PIP), determine the feasibility of achieving each of the targets set in the PIP within the remainder of the Project life, and recommend the actions which would be necessary to achieve the goals that are considered to be realistically feasible.

e) Review not less than three economic studies of small hydropower projects and other ELECTROPERU projects to determine their rates or return, costs, benefits, etc. Examine also their importance within the social and development priorities of the GOP. Based on these reviews, discuss the issues and make recommendations on

the size and position that future small hydropower projects should have within the overall power development program of the Peruvian government.

f) Provide a comprehensive analysis of the successes and failures of the Project, with special attention directed to how problems can be overcome in the remaining life of the Project and in a future similar project.

## 2.4 Methodology Employed in the Evaluation

In accordance with the scope of the evaluation as specified in the terms of reference, the required work has been completed through the following general activities:

- interviews of personnel of ELECTROPERU, Regional Companies, AID, the Ministry of Energy and Mines (MEM) and other organizations involved with the project and with the country's electrification efforts, as well as beneficiaries of the SHPP;

- visits to the regions and sites of two sub-projects which are still underway and two which have already been completed;

- examination and analysis of progress reports, prefeasibility and feasibility studies, drawing, contracts and other pertinent documents; and

- comparison of the completed sub-projects and their verifiable results with the designs and forecasts presented in the corresponding studies.

Appendix 2 of this report presents a list of the people interviewed. Appendix 3 lists the most important documents and reports which were reviewed. The sub-projects visited included the already-completed Chongos Alto and Cajabamba SHPP, and the San Marcos and Namora SHPP whose construction is still in progress.

Only a limited comparison of actual and predicted results has been possible, since only three SHPP have been completed, and these three have been operational for only a very short time. Cajabamba and Pucará became operational a little more than a month ago. Chongos Alto began operating early in 1986 but as it still does not operate between 8 a.m. and 4 p.m.; productive uses of its power have not yet been developed. However, Section 7.3 presents certain observations on this subject. In Appendix 10, actual costs are compared with the costs estimated in the studies.

## 2.5 Members of the Consulting Mission

The consulting team that carried out the evaluation of the Project was made up of the following persons:

- Dr. Richard J. Morris, Economist and Team Coordinator;

- Mr. Alberto Val, Engineer and Expert in Organization and Management of Electric Power Companies and Hydroelectric Works; and

- Mr. Kearon Bennett, Engineer and Specialist in Small Scale Hydroelectric Projects.

The members of the team performed the evaluation tasks in accordance with the responsibilities indicated above and their own relevant experience. Messrs. Morris and Val dedicated approximately four weeks to the work, beginning on September 29, 1986. Mr. Bennett worked from October 6 to October 18. Visits to the sub-project regions and sites took place October 8-12 (Cajabamba, San Marcos and Namora) and October 18-20 (Chongos Alto).

# 3. DEVELOPMENT OF RURAL ELECTRIFICATION IN PERU

## 3.1 Brief History of Rural Electrification

Peruvian rural electrification policy was initiated in 1963 when a Technical Assistance Agreement was signed with AID to select an area in the Mantaro Valley where a Rural Electrification Pilot Plan would be implemented. After the Pilot Plan was concluded, rural electrification moved rather slowly. Until 1973, when ELECTROPERU was created, public power was supplied mostly by private enterprise, which tended to serve only the more profitable large urban centers.

For several years after ELECTROPERU's creation, its activities were limited to improving the provision of electricity to large and medium size population centers. Only after 1978 did it begin to direct its efforts towards increasing rural electrification. That year the Ministry of Energy and Mines (MEM) implemented a new program:

- In November 1978 top priority was assigned to the Small Hydroelectric Power Plants (SHPP) Program and a special steering commission was created.

- In December 1978, ELECTROPERU created the Office of the Program for Applied Technology, charged with monitoring and coordinating the SHPP Program. The SHPP Electrification Fund was also established, using ELECTROPERU's internal resources.

- In 1981, the Provincial, District and Rural Electrification Division was created. It later became a Department within the Construction Division at ELECTROPERU.

- In June 1981, Legislative Decree No. 163 levied a tax on electric power consumption to finance rural electrification construction costs.

- In 1982, the General Electricity Law No. 23406 was passed. The law called for a planned national electrical development, created the Regional Electric Companies, and specified the preparation of the National Plan for Expansion of the Electric Frontier. In 1983, the Provincial, District and Rural Electrification Division prepared the first version of the Plan.

A rural electrification program was thus established with the following objectives:

- to meet the energy needs of the country's microregions and isolated communities;

- to make use of the large number of small potential hydroelectric sites in the interior, mainly in the Sierra;

- to substitute hydroelectric power for petroleum-based generation of electric power; and

- to develop a domestic capability and technology for manufacturing hydroelectric equipment and for constructing the power plants.

Because of the vastness of the country's water resources, no major efforts have been devoted to electrifying rural areas with other energy sources such as solar, wind, geothermal, biogas and biomass. However, in 1985 ELECTROPERU did create the Non-Conventional Energy Office for this purpose.

Peru's large territory (1,285,000 $km^2$) and broken topography can be grouped into the following three areas: the coast (Costa); the mountains (Sierra), where elevations exceed 5,000 meters (16,000 feet); and the jungle (Selva). The Peruvian government has concentrated its studies of small river basin exploitation in the upper elevations of the Sierra, i.e. at the headwaters. Because of this policy, developments typically have heads of 80 to 200 meters (260-650 feet) and flows of 0.2-0.6 cubic meters/second (7-21 cubic feet/second), which result in hydroelectric power plants with 100-1,000 kW capacities. It can be assumed that there are more than 1,000 sub-basins with hydroelectric potential that together could produce a total of one million kW.

At the end of 1984, there were in Peru some 1,000 population centers with electric power, 58% of which were supplied by ELECTROPERU via the Regional Electric Companies. An additional 25% of the electric power services were managed by municipal councils and 17% by autoproducers (mining centers, agricultural cooperatives, petroleum companies, etc.).

It has been estimated that towards the end of 1984 there were 350,000 subscribers in small and medium size population centers, which would indicate an electrification rate of approximately 17% for this population sector. Assuming that the rural sector comprises 50% of that population, electric power was being provided to about 5% of the rural population at that point in time.

There are in Peru over 1,100 population centers with hydroelectric development potential; these centers have a total population of about 2 million people of which 53% presently have no electric power at all. The remaining 47% are supplied with energy primarily from thermal power plants, many of which are in poor condition due to their age and poor maintenance history. These power plants are very costly to operate because of their high fuel costs. Moreover, they supply power only for public lighting and home use, and often for only a few hours per day.

As regards the electrification of rural areas, the situation is even more critical, since the percentage of homes without electricity exceeds 95%.

## 3.2 Rural Electrification Programs and Projects

The National SHPP Program was begun in 1978. It encompassed isolated communities and microregions and included inventory, prefeasibility and feasibility studies, as well as the construction of approved projects.

From 1980 to the present, 36 SHPP, each with an installed capacity of up to 1,000 kW, have been placed in operation. These include the three mini-hydro plants financed by the AID Project which are now operating as well as 12 micro-hydro plants (with an installed capacity of less than 100 kW). Four of the 36 are presently out of service as a result of terrorist attacks or other causes. If all the SHPP built since 1907, most of which are in rural areas, are taken into account, there are presently 105 operational and 42 paralyzed power plants (see Appendix 4):

| | Number of SHPP | | |
|---|---|---|---|
| Capacity (kW) | In Service | Paralyzed | Total |
| 0-100 | 53 | 34 | 87 |
| 101-1000 | 45 | 8 | 53 |
| More than 1000 | 7 | | 7 |
| Total | 105 | 42 | 147 |

In addition to the SHPP which have already been placed in service, the National Plan for Expansion of the Electric Frontier for 1985-1990, as updated in May 1986, includes 92 new projects for generating electrical power in rural areas. The Plan includes primarily hydroelectric power plants of up to 5 MW, with a total capacity of 93 MW. In some micro-regions, combined hydro and thermal generation is a technically and economically preferable alternative, and, in a very few locations, thermal plants are the best choice. Eleven of the projects would have capacities ranging from 1,000 to 4,500 kW; the remaining 81 range from 64 to 1,000 kW. Several of the projects are already under construction. The Plan also includes 43 other projects for expansion of the distribution networks.

Aside from the projects which are already part of the National Plan for Expansion of the Electric Frontier, the Electrification Project Units have submitted new packages with a preliminary total of 90 proposed projects. While financing is sought, these proposals are being studied and prioritized through a quarterly updating process.

The original Plan for the 1985-1990 period involved an estimated expenditure of US$213 million, the financing of which ELECTROPERU sought to share with several international development agencies and friendly countries that wished to cooperate in rural electrification projects. Aside from the financial resources which could be obtained abroad, the following domestic resources are available for the mini-hydro program:

a) Legislative Decree No. 161, as amended in 1985, which levies a 10% tax on the consumption of less than 150 kWh/month and a 25% tax on the usage of more than 150 kWh/month. ELECTROPERU must use 50% of the

total tax revenues for the Provincial, District and Rural Electrification Program. In 1986, this represented a budgeted investment of the equivalent of US$33 million.

b) Expansion Fund. The General Electricity Law created this fund with payments from new users of electric power and the annual fee fixed by the National Rates Commission, which may not exceed 10% of the total value of the annual investment in distribution systems.

c) Departmental Development and Special Projects Corporations. These organizations coordinate with ELECTROPERU the management of a portfolio of electrification projects. Yearly amounts available for investment from these sources are estimated to be on the order of 20% of the funds generated by Legislative Decree No. 163.

d) Housing Bank of Peru, which makes available up to US$1.8 million per year to finance the construction of distribution networks.

e) Other sources, which include private banks, the mutual savings and loan system, savings cooperatives, finance companies, etc.

To date, the following outside financing sources have been approved (see also Appendix 5):

a) Agency for International Development (AID)

The AID-sponsored program is that which is discussed in the present report.

b) United Kingdom

On March 15, 1982 a services and supplies contract was signed for small- and medium-sized hydroelectric plants and the associated transmission systems for the 1982-1990 period. Financing consists of a 4.8 million pound sterling grant, plus a 20.8 million pound sterling loan earmarked primarily to pay for British technical services and equipment for 21 power plants, with a total capacity of 42,000 kW.

c) Federal Republic of Germany

On July 9, 1981 an agreement was signed for the development of non-exhaustible energy sources and small hydroelectric energy resources for rural electrification, with the following objectives:

- to prepare an overall program for the development of regional and local electrification plans and the implementation of hydroelectric projects;

- to formulate electrification projects at the feasibility study level in the model regions; and

to prepare definitive studies for four pilot projects with a total capacity of 2,110 kW, and to supply the machinery for two of those projects.

The agreement includes a grant of two million German marks for equipment and materials for the hydroelectric plants to be built as pilot projects and for technical assistance (198 person-months).

It is estimated that the three agreements together could finance the construction of 35 hydroelectric power plants with a total capacity of 50 MW, which would provide electricity to over 500,000 people.

In addition to the above three agreements, bids were requested between May 1980 and January 1981 for the provision of hydroelectric equipment for 21 power plants with a total capacity of eight MW. Contracts were awarded to Somerin (Brazil) for US$205,000, Sercenco (USA) for US$1.3 million, and the National Chinese Corporation for US$1.4 million. The projects were not properly implemented because of a shortage of resources and a lack of final designs, and work was suspended for several years. ELECTROPERU has now decided to complete the studies and build the facilities under force account, thereby providing electric power to over 200,000 inhabitants.

Apart from the mini-hydro projects contemplated in the various agreements, as the result of a suggestion of the Ministry of Energy and Mines, approval has been given to employ COMMSA, a state-owned consulting firm attached to CENTROMIN, to evaluate and compile an inventory of Peruvian river basins. COMMSA would seek the support of several domestic consulting firms, over a one-year period, to investigate the hydrology of the basins and collect other pertinent data needed for prefeasibility studies. COMMSA will also be entrusted with most of the final studies, although some may be subcontracted out to private consulting firms.

# 4. INSTITUTIONAL DEVELOPMENT OF ELECTROPERU

## 4.1 Project Organization and Management

The Project has suffered the effects of several organizational and management changes in ELECTROPERU, as described below.

### 4.1.1 Project Implementation in ELECTROPERU

ELECTROPERU initially assigned the responsibility for implementing the Project to the Office of the Program for Applied Technology (OPAT), which operated at the divisional level and reported directly to the General Manager. Within OPAT there were offices that supervised the AID Project and the Agreements with other countries. In 1981, the OPAT was replaced by the Office of Hydrogeneration of the Provincial, District and Rural Electrification Division. The AID Project Office was re-established within the Rural Electrification Division and continued with the direct implementation of the Project, including the technical assistance as well as the development of the SHPP.

More changes occurred in 1982 when the General Electricity Law was promulgated and the regionalization process was begun with the creation of an Electrification Project Unit (EPU) in each region. These ELECTROPERU offices were responsible for promotional activities, supervision of the construction of SHPP, and the execution of SHPP projects by force account. After the EPU were created, the AID Project Office worked through them to implement the construction projects. When construction is complete and the mini-power plants are operational, they are transferred to the Regional Electric Companies (REC), which are in charge of managing, operating and maintaining them.

A further organizational change took place at the end of 1985 when the Provincial, District and Rural Electrification Division became a Department within the Construction Division. This final structure, illustrated in Appendices 6 and 7, is still in effect.

### 4.1.2 Support of the Project by ELECTROPERU

The effects of the decentralization and the reorganizations, as well as other factors, including a rather slow completion of certain initial conditions by ELECTROPERU, put the Project behind schedule. However, after the regionalization took effect, the organization of the AID Project Office was consolidated, and following the initial period during which ELECTROPERU's support of the Project was not very enthusiastic, a more determined and stable support has lately been provided.

However, one aspect of the Project that has not received the same support that ELECTROPERU has generally given to the construction projects is the technical assistance program. The provision of assistance has not met expectations. The reduction of the amount of the Grant from US$1.0 million



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to US$750,000, because of non-use of the funds (see Section 4.5), reflects a deficiency that hopefully can be overcome in the future projects that are being considered.

Section 4.1.3 details other aspects of Project management that would benefit from a greater support by ELECTROPERU's senior staff.

### 4.1.3 Management and Organizational Problems Encountered

After analyzing the period of implementation of the Project, including the two extensions, several problems that have hindered its progress, some of which have not yet been overcome, have been identified:

a) The development and application of the sub-project evaluation methodology took longer than expected.

b) Delays took place in the approval of the terms of reference and specifications for carrying out the feasibility studies and the construction of the sub-projects, primarily in the Legal Office and the Financial Division.

c) The completion of the sub-projects has not proceeded in a timely manner because of the complexity of the bureaucratic process, in which decisions are required at all levels from the Rural Electrification Department to the Board of Directors. These activities still take more time than scheduled which increases the cost and duration of sub-project implementation. (See Section 4.3.)

d) Significant delays have occured in the payment of consultants and in the approval and signing of contracts for the procurement of machinery.

e) The continual organizational changes in ELECTROPERU added to the departure of several of the Project's technical staff, created an air of uncertainty in the unit responsible for implementing the Project. These factors have tended to blurr the ultimate objective, that of establishing a stable and experienced unit capable of continuing rural electrification in ELECTROPERU through more ambitious programs in the future. In effect, the personnel of the Project Office are preoccupied with the future of their unit and the objective of the Project has been reduced merely to finishing the sub-projects included in the Agreement. The performance of the Project Office has also been affected significantly by the personnel reductions.

f) Within the Rural Electrification Department, the AID Project Office is a direct dependent of the Special Projects and Agreements Unit, which also oversees the German and British project offices, among others (see Appendix 7). The position of head of the Special Projects Unit has been vacant for several months, which has made difficult the implementation and coordination which the component sections must carry out. Also vacant is the position of head of the Planning and Scheduling Unit. These deficiencies make the job of the Manager

of the Rural Electrification Department more difficult, as he must dedicate a large part of his time to relations with other entities of ELECTROPERU and with outside organizations, as well as coordinate the internal functions of his Department.

g) The distribution and organization of the information required to manage efficiently the rural electrification program are not adequate.

h) The Rural Electrification Department is not moving Project funds rapidly enough to complete the disbursement of the available Loan and Grant balances prior to the Project Assistance Completion Date (May 19, 1987). The absorption of the Electrification Project Units by the Regional Electric Companies (see Section 4.6) will seriously aggravate this situation. The relationships among ELECTROPERU, the EPU and the REC are still undefined as regards the implementation and supervision of sub-projects and the flow of Project funds. At present there is a balance of approximately US$900,000 of advances already disbursed by AID for which the Project Office has not yet presented a final accounting to AID.

4.1.4 Actions Recommended to Strengthen Management

a) ELECTROPERU should make a greater effort to facilitate the relationships of the Project Office with other offices and should fill the existing vacancies.

b) It is important to try to restore the Project's ultimate objective. Attempts should be made to retain the technical personnel that have been trained during the past six years, and to integrate them into an ELECTROPERU unit that would be able to undertake successfully future rural electrification programs based on mini-hydro plants.

c) The salaries of the contract employees of the Project Office and the regional EPU should be increased. To the extent possible, these employees should be given greater job security and should not be required to renew their contracts annually, since the present procedure engenders a permanent feeling of employment insecurity.

d) The EPU should be allowed to maintain their present composition and authority, without disturbing the flow of Project resources.

e) ELECTROPERU should immediately begin to collect and compile, in a central and integrated data base, all the information available both within and outside the institution relating to hydrology, meteorology, topography, geology, energy demand, consumption of electricity, other socio-economic indices important for the prefeasibility and feasibility studies, and an inventory of existing SHPP. In addition to maintaining this information in a central data base, ELECTROPERU should organize teams of technical personnel to ensure the permanent gathering and recording of the data as well as to coordinate activities with other institutions. For example, while the power plants are being built, rainfall and stream flow measurements can be taken



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by construction personnel, and once the plants are in service, the data can be collected by operating personnel.

f) An effort should be made to improve the internal coordination and the availability of information in the Rural Electrification Department. Assigning personnel to job vacancies, particularly at the unit head level, or replacing those positions with another that would assist the Manager of Rural Electrification, would contribute to achieving this goal.

g) Attention should be given to paying invoices and accounting for completed work more expeditiously, thereby avoiding the accumulation of idle funds and delays in the use of funds and the final accounting of completed sub-projects.

## 4.2 Studies and Selection of Sub-Projects

For the evaluation of the sub-projects considered for funding by the AID Project, the Project Office developed an analytical methodology that has come to be known at ELECTROPERU as the "AID Methodology". This methodology has been used in both the prefeasibility and the final feasibility studies.

The latter studies have also included the design of the SHPP as well as detailed quantity and cost estimates and the preparation of the tendering or implementation documents.

Almost all the prefeasibility studies and three of the final feasibility studies were prepared by ELECTROPERU. The other final studies were contracted to local consulting firms.

### 4.2.1 National Economic Evaluation Methodology

The methodology for economic evaluation at the national level, which includes the consumer surplus concept, was prepared on the basis of the approach recommended by Arthur D. Little, Inc. This approach was revised and expanded in certain respects to incorporate analytical procedures used previously in ELECTROPERU as well as procedures for forecasting the demand for electric power. A brief description of this methodology is presented in Appendix 8.

In general, the methodology developed (which is known internally at ELECTROPERU as the "AID Methdology") has satisfactorily fulfilled the objective of its preparation and use, which is the consistent verification of the economic viability of the various sub-projects, allowing for the selection of those which would produce the greatest benefits.

In view of the methodology's successful use in the evaluation of the AID-funded sub-projects, it will also be used in future SHPP studies commissioned by ELECTROPERU. For example, all the studies done by or through COMMSA, the consulting firm recently chosen by ELECTROPERU and



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the Ministry of Energy and Mines to carry out most of the future SHPP studies, will use the "AID Methodology".

The methodology was formulated without much information on the demand for electricity or SHPP costs. Much more information is now available as a result of the experience gained in building and operating the new plants. It would be reasonable now, as a first step in the development of an evolving and ongoing methodology, to review the initial assumptions and to update them on the basis of the new information that is presently available. Aspects of the methodology that would be susceptible to modification and enhancement include the following:

a) The curves which are used to forecast the electrification coefficient (residences with electricity over total number of residences). The coefficients obtained from the curves used to date appear to be too low (see Section 7.3.1).

b) The curves for unit household and public lighting consumption as a function of the number of subscribers. The current curves are estimates based on limited data. An analysis of the actual power consumption patterns in the areas served by the recently-built SHPP could verify the validity of the curves or lead to the estimation of unit consumption as a function of another independent variable (such as time) with different upper and lower limits. Distinguishing among urban, suburban and rural users might also be useful.

c) The assumptions regarding the number of residential subscribers per commercial subscriber and the unit consumption of commercial subscribers.

d) The set of data obtained from the survey of the consumption of energy from other sources "without the project". Gathering this information has turned out to be somewhat expensive, such that ways to reduce data collection costs should be sought, perhaps by identifying common consumption patterns in communities with similar characteristics. Such an approach would allow the development of unit consumption figures and the forecasting of total consumption based on preestablished standards, according to the classification of the community or town. (Usually, this data is compiled for the prefeasibility study but is not updated in the final study.)

e) The expression for estimating operating and maintenance costs as a function of installed capacity. Actual costs of the plants already in operation could be used to verify the validity and update the form and coefficients of the equation, particularly those related to the labor required to operate the SHPP.

f) Elimination of the working capital cost. Although this is not a large amount, it should not be included in an analysis from the national viewpoint, as it does not represent a consumed resource but rather a transfer payment.

g) Comparison with other sources of electric power. The petroleum costs used in the comparison with the thermal alternative have changed and should be updated. Explicit consideration should also be given to the alternative of extending transmission lines from another plant or from the interconnected grid. (For example, the interconnection of the San Marcos and Namora distribution systems might have permitted postponing the construction of one of those SHPP and could have been considered as an alternative.)

### 4.2.2 Evaluation of the Final Studies

For purposes of evaluating the studies, the Cajabamba and San Marcos Final Feasibility Studies, including the design of the SHPP, were reviewed. The former study was prepared by ELECTROPERU and the latter by a consulting firm.

Also reviewed, but in less detail, were the studies and designs of the Chongos Alto sub-project, prepared by ELECTROPERU, and the Namora sub-project, prepared by the same consulting firm. The following comments refer to the studies themselves as well as to the concepts and design philosophies employed.

a. Economic Evaluation of the Projects

The economic studies were carried out in accordance with the above-mentioned "AID Methodology". The studies prepared by the consulting firm do not update the demand forecasts developed by ELECTROPERU in the pre-feasibility studies, nor do they present the formulation of the demand forecasts on which the economic analyses are based. The forecasts used in the final studies exceed substantially those which were presented in the prefeasibility studies:

| | | San Marcos | | Namora | |
|---|---|---|---|---|---|
| | | Prefeas. Study | Final Study | Prefeas. Study | Final Study |
| Maximum demand (kW) | 1987 | 315 | 389 | 146 | 231 |
| | 2000 | 723 | 686 | 324 | 368 |
| Consumption (1000 kWh) | 1987 | 810 | 1,087 | 360 | 569 |
| | 2000 | 1,635 | 2,327 | 895 | 1,080 |

Although the differences are assumed to result from an updating of the prefeasibility studies, the bases on which the data in the reports were updated could not be verified.

In the case of the Chongos Alto final study, the first that was prepared, the costs of transmission lines and distribution networks were not included in the total cost figures used in the evaluation of the sub-project and the calculation of the benefit/cost ratio, which resulted in the over-estimation of the latter measure of economic viability. This deficiency was corrected in subsequent studies.

As part of the economic evaluation of the sub-projects, economic and financial evaluations from the point of view of ELECTROPERU as a firm were prepared. In all cases, it was determined that ELECTROPERU would not recover its costs and that the sub-projects would not be profitable.

The conclusion that the sub-projects would not be commercially viable is a direct consequence of the tariff policy of the government, whose Tariff Commission generally sets user charges at a level that covers only the operating and maintenance costs of the entities responsible for these functions (presently the Regional Electric Companies). There is no attempt to recover capital costs. Given this situation, it does not make much sense to incur the cost of carrying out an economic and financial evaluation of the investment from the viewpoint of the firm.

b. Design Concepts and Technical Studies

In general, the sub-project designs were prepared at a level of detail that is not justified by the mediocre quality and imprecision of the basic information that is available. This is particularly true of the studies done by the consulting firms.

Most of the basic data available on hydrology, topography and geology is not very reliable, and the small size of the projects does not justify lengthy and costly research to improve the reliability. The SHPP designs should reflect this situation; they should be as simple as possible, and they should be sufficiently flexible to allow for modification in the field, as dictated by the actual conditions encountered when the projects are implemented. (The tendering and contracting process should also reflect this situation. See Section 4.3.)

For example, in the construction of the canals of several of the SHPP, the contractors have claimed that the required excavation in rock has substantially exceeded the anticipated quantities, because of the insufficient geological information that was provided. However, a more thorough evaluation of sub-soil conditions along a canal several kilometers long would require a time-consuming and very costly study. In such cases, it would be preferable to avoid the cost and delay of further study and proceed with the work under a system of flexible designs.

On the other hand, the preliminary studies must identify the requirements, the principal factors that affect costs, and the potential problems that could be encountered because of the lack of adequate information (such as the need for an unforeseen 150 or 200 meter tunnel in San Marcos), as well as the appropriate location for the major structures (such as the penstock and the powerhouse in Namora, which were poorly located in the original design).

In small projects such as the SHPP covered by the AID Agreement, standardized designs can help to reduce costs and facilitate efficient development and implementation. (The sand trap designs, for example, show great variation.) Emphasis should be placed on simplicity and uniformity. Several projects seem overly complex when the design flow and

plant capacity are considered (for example, the intake works at San Marcos, as compared to the intakes at Chongos Alto and Cajabamba).

In general, the design flows and capacities were based on an excedence value of 90% (i.e., the actual flow is expected to exceed the design flow 90% of the time, allowing the power plant to operate almost always at its maximum capacity). In several cases, stream flow data were unreliable, and average daily flows had to be estimated on the basis of information available from gauging stations elsewhere in the vicinity.

Although a design based on a 90% excedence value can be justified in an isolated system that uses only hydro-generated power, such a standard might not always be appropriate for hydro/thermal systems where both a diesel plant and a SHPP are needed to cover the entire demand. In the case of San Marcos, for example, a SHPP with a higher capacity and a lower excedence value could have been considered as an option that would have displaced the thermal generation during periods of greater water availability. The viability of such an option would, of course, depend on the sufficient duration of the higher flows.

Another factor to be considered in designing the plants is the possibility of future expansion, particularly where there is great uncertainty with respect to available flows or where it may be possible to interconnect with other plants or systems. In San Marcos, for example, a higher capacity canal could have been designed without increasing very much the cost of the sub-project. Then, if the flow of water in the river should exceed the design flow, the capacity of the plant could be increased in the future at a reasonable additional cost if the canal were already sufficiently large and if the other structures had been designed to facilitate a corresponding expansion. Otherwise, increasing the capacity of the canal at a later stage would be very costly.

In summary, the technical studies were generally too complex in comparison with what is needed for this type of project. The complexity and excessive detail are more notable in the studies prepared by the consulting firms than in those prepared by ELECTROPERU. Had there been closer supervision by ELECTROPERU, the studies prepared by the consultants would have been more appropriate, and the resulting construction delays might have been avoided.

### 4.2.3 Review of Criteria for the Selection of Sub-Projects

The ten sub-projects implemented under the AID Agreement were selected primarily because of their economic viability, with consideration having been given also to their technical feasibility and their location in regions which had already benefitted from other AID-funded projects and to which the GOP had assigned a high development priority. However, aside from having been employed to evaluate the AID-funded sub-projects, the economic rate of return criteria, usually measured by the benefit/cost ratio, is not generally used by ELECTROPERU as a basis for the selection of projects or the establishment of implementation priorities.

To assign priorities to the projects encompassed by the National Plan for Expansion of the Electric Frontier, which, with few exceptions, tend to be isolated systems of less than 2.5 kW capacity, the Planning Office of the Rural Electrification Department has devised a ranking system based on the assignment of points in each of several different categories. Fifteen categories or evaluation factors have been defined, with each category having arbitrarily been given a maximum value, as follows:

| Evaluation Factor | Maximum Scores |
|---|---|
| Present status of the study | 5 |
| Electrical infrastructure | 11 |
| Demand for electricity | 6 |
| Utilization of sources of energy | 10 |
| Physical progress | 10 |
| Financing | 10 |
| Committed investment | 10 |
| Investment per subscriber | 15 |
| Substitution of hydropower for thermal power | 5 |
| Population to be served | 9 |
| Geographic location | 6 |
| Existing infrastructure for access | 9 |
| Population growth rate | 5 |
| Priority of the microregion | 18 |
| Level of community organizations | 3 |
| Total | 132 |

Each factor has an associated scale from which points are assigned to each sub-project according to its relevant characteristics. Project implementation priorities are determined on the basis of the total number of points assigned.

The weighted factor method suffers several defects. For example, the relative weights of the factors are arbitrary and very subjective, the factors give very little weight to the economic viability of projects, and the results do not necessarily lead to an increase in national wealth and welfare.

A much more rational approach would be to assign priorities initially according to the benefit/cost ratios. If necessary, these priorities could be adjusted to take into account government policies with respect to factors such as the geographic distribution of investments or the type of financing available. The benefit/cost ratio of a project implicitly includes an evaluation of several of the factors which are assessed individually in the weighted factor method.

### 4.2.4 Recommendations for Improving Studies and Selection of Sub-Projects

It is understood that the Ministry of Energy and Mines has suggested to ELECTROPERU that most of the SHPP final feasibility studies be given to COMMSA, a publicly-owned consulting firm, and, through COMMSA, to private firms. To ensure that the studies given to COMMSA and other future

studies are highly useful and that they facilitate the implementation of the projects, the following measures are recommended:

a) Compare actual SHPP results with the results forecast in the feasibility studies, with emphasis on demand and cost behavior. (See Section 4.2.1.)

b) Based on the above review, adjust the methodology for forecasting demand and cost and for the economic evaluation of the sub-projects, with the objective of simplifying the performance of the studies and improving the quality of the results.

c) Based on the ELECTROPERU's experience to date, develop simple standardized designs for the various components of the SHPP, specifying the conditions that govern their selection and use.

d) Try to develop the concept of simplicity and flexibility of design in the consulting firms, in keeping with the quality of the basic information that is available, with the intent of facilitating construction and reducing construction costs.

e) Extend the technical studies to evaluate various SHPP design capacities, taking into account the possibilities of future expansion or of interconnection with other plants or systems, especially in cases of interconnection with thermal plants. An analysis of several typical situations could be carried out to establish standards and guidelines.

f) Establish a strict supervision of the performance of the studies to ensure that the results are satisfactory, especially with respect to the collection and use of topographical and geological information, design concepts, and the identification of potential construction problems.

g) Revise the procedure for assigning priorities to the sub-projects, giving a greater weight to the benefit/cost ratio. Once priorities have been assigned using this factor, appropriate and necessary adjustments can be made to take into account government policies with respect to other factors such as regional priorities.

h) Consolidate the "AID Methodology", or a modification thereof, as the sole technique for evaluating SHPP projects in the Rural Electrification Department.

## 4.3 Tendering, Awarding and Contracting of Works and Equipment

The complexity and slowness of the tendering, awarding and contracting process has had the effect of substantially delaying the advancement of the Project. With the desire to improve the procedures and expedite future projects, the process is analyzed below and the resulting recommendations are presented.

### 4.3.1 Review of Procedures and Requirements

Once the feasibility studies and the designs of the facilities to be built have been completed, generally through consulting firms contracted by the Rural Electrification Department, the corresponding notices are published and possible bidders are given a period of approximately 90 days to submit their proposals.

For civil works, the Procurement Office provides bidders with the official budget and complete documentation that includes fully detailed designs and drawings, forms with estimated quantities and spaces for unit prices, terms of reference, technical specifications, descriptive information, and all the questions and answers that arise prior to opening the sealed bids. Proposals submitted by contractors must remain valid for at least 90 days.

Once the proposals are received in Lima, a committee is formed in the Rural Electrification Department with one of the members being a representative of the corresponding EPU. The Committee proceeds to evaluate the bids and select the winner in a process which usually takes 90 days through the formal approval of the award.

The bid evaluation procedure required by the RULCOP (Unified Regulations for Bidding and Contracting of Public Works) and used by ELECTROPERU is the following: Proposals that are more than 10% above or below the average of all the proposals submitted, including the official budget, are eliminated. The remaining proposals are once again averaged, and the offer that is closest to the average, without exceeding it, is recommended for the award. At AID's suggestion, ELECTROPERU agreed to award Project contracts to the lowest bidder from among pre-qualified firms, without first eliminating any offers.

Although it is clear that the awarding process is complex and there is no perfect solution, it is preferable to eliminate proposals that are too low and that will certainly create problems during project implementation.

Once the formal award has been recommended, the process of preparing and signing the contract requires approximately 45 days, followed by another fifteen days for work to begin.

The contracts that are approved in the Rural Electrification Department are lump sum rather than unit price contracts. Since the design studies generally suffer from insufficient geological, hydrological and topographic information, which introduces some degree of uncertainty in the designs prepared by the consultants, unforeseen problems, sometimes major ones, are encountered when the works are implemented, the cost of which the contractors are not willing to absorb. As a result, claims are submitted and are followed by higher costs and delays.

The above process is repeated for the contracting of the electromechanical equipment (for which international tendering is allowed) and for the electrical works, including the primary distribution network. However,

the civil works are normally the most extensive and constitute the critical path, accounting for 30% to 50% of the total cost.

At the same time, in order to have the power plants become operational without delays, the secondary lines and domestic hookups must be budgeted and awarded, as a different implementation and financing process must be followed.

In summary, the entire process, from the requesting of proposals through the initial operation of the power plants, takes approximately 26 months, as shown in the following diagram:

| | |
|---|---|
| | Request for Bids |
| Submittal of Proposals - 3 months | |
| | Receipt of Proposals |
| Examination of Proposals - 3 months | |
| | Awarding |
| Preparation of Contract - 1-1/2 months | |
| | Signing of Contract |
| 1/2 month | |
| | Initiation of Work |
| 18 months | |
| | Provisional Reception of Facilities |
| Total Time 26 Months | |

This process is even slower when a challenge is presented by firms that are not awarded the contract. However, this problem has been overcome by requiring a deposit before a challenge is accepted.

### 4.3.2 Definition and Treatment of Contingencies

The definition of "force majeur" employed in Project contracts, in accordance with RULCOP stipulations, is any unavoidable act or event that affects the fulfillment of the contractor's obligations, as long as it is not caused by the contractor (heavy rains, total interruption of the road system, etc.). "Force majeur" is accepted by ELECTROPERU, and reasonable additional payments and extensions are granted.

Except for the problems caused by terrorist acts, wars, natural disasters, etc., the contracts leave most contingencies to the account of the contractor, within the lump sum mode. However, in this type of project,

characterized by insufficient topographic, geological, and hydrological data, designs cannot be as precise as is normally required for a lump sum contract. There have been unforeseen items, proportionately of great significance, for which the contractor has not been responsible and which probably were not included in his proposal.

The present treatment of unforeseen items is not the most appropriate for projects of this type, which consist primarily of civil works of low total cost, with insufficient preliminary investigations and designs which are very vulnerable to change.

If the contractors are forced to include these unforeseen items in their proposals, they will probably increase their prices by 40% to 60%, requiring ELECTROPERU to pay the higher prices, whether or not the contingencies actually occur.

If, instead of the lump sum system, unit price contracts were used, most of the contractor claims for differences between actual quantities and the quantities estimated in the bidding documents could be eliminated.

In cases in which unforeseen items could be significant, the implementation of the projects by force account, which ELECTROPERU has done rather successfully, would probably be preferable to incurring delays as the result of large contractor claims.

In the San Marcos sub-project, which is still under construction, a contingency has arisen which could require the digging of a tunnel of nearly 200 meters in length which was not included in the design. The contractor took advantage of the opportunity to demand additional payments and more time and halted the construction of the canal while awaiting a decision that must be approved by ELECTROPERU's directors and the Comptroller General of the Republic, which could take months.

Given this situation, the force account solution to building the tunnel would appear to be a viable option, either directly by ELECTROPERU or by delegating it to the contractor.

### 4.3.3 Development of Local Manufacturing Capability

An important part of rural electrification, both technically and economically, is the encouragement of the development of a local consulting, contracting and equipment manufacturing capability.

For the manufacturing of equipment, sufficient local industrial capability would appear to exist, although all the necessary experience has not yet been obtained. Some past attempts at manufacturing were not successful. Nevertheless, local firms have presented bids in recent procurements, have been awarded contracts, and have manufactured turbines and generators that are presently in service.

A reduction in costs and in the use of foreign exchange could be achieved if private initiative were encouraged and most of the electromechanical and electrical equipment were manufactured locally.

### 4.3.4 Recommendations for Accelerating the Process and/or Reducing Costs

a) Contracts should be awarded based on the lowest reasonable offer, with the receipt of proposals only from prequalified firms.

b) It would be preferable to use the official budget as an important reference for evaluation of the bids, without disclosing it to the bidders beforehand.

c) Most contingencies that are a function of insufficient hydrological, geological and topographical data should be removed from the contractor's responsibility.

d) Contracts should be awarded on the basis of unit costs, total costs and implementation period. In addition, the contractor should be obligated to carry out work delegated by ELECTROPERU under force account, when requested and justified by the inspector.

e) An attempt should be made to facilitate the tendering, awarding and contracting process through an analysis of the sequence of activities and the identification and correction of bottlenecks. The approval of awards and contracts at lower levels of decision (for example, at the Construction Division level) should be considered.

f) ELECTROPERU's support of local industry should be improved to the point allowed by existing regulations, either by giving reasonable preferential treatment to domestic over foreign manufacturers (although AID rules do not permit such advantages) or by providing them with technical assistance in developing simple and sturdy designs which are easy to maintain.

g) The encouragement of local industry should also include an attempt to create an attractive and stable market that will allow for the development of an ongoing program for manufacturing various types of electromechanical equipment.

## 4.4 Supervision and Execution of Construction Projects

This section analyzes the experience gained through the supervision of contracted construction and the implemention of projects by force account and presents recommendations for facilitating these activities.

### 4.4.1 Implementation by Force Account or by Contract

When dealing with large projects, it is generally true that they can be implemented by contract with better quality, in a shorter period and at a lower cost than can be achieved by force account.

In contrast, when the projects are small and do not require very expensive or sophisticated construction equipment, the decision to implement by contract or by force account can depend on the reliability of the

basic information, the quality of the design or the availability of qualified technicial personnel to supervise and carry out the construction. If the project's design is complicated or not clearly defined, or if because of rugged topography there is a likelihood of encountering major unforeseen construction problems, an alternative that could prove beneficial is to build by force account.

In the specific case of the small hydroelectric plants, it is possible to construct them with similar quality and project duration via force account rather than by contracting, and at a lower cost.

The key reason for the cost difference is that ELECTROPERU has been able to speed up construction without having to stop to negotiate additional costs or differences in quantities that arise as a result of design changes or errors in the basic information provided (topography, geology and hydrology). The major reasons for the difficulties encountered in the contracted projects are:

- designs are too detailed and the official budgets do not reflect the conditions found in the field;

- procedures for the approval of additional costs are long and complicated; and

- awarding contracts based on an official estimate forces contractors to accept the specified quantities, and they are not motivated to propose prices that could be more realistic in accordance with their own research and estimates.

It is important to point out that if detailed and extensive hydrological, topographic and geological studies of an area are not available, there will always be a need to modify the alignment or location of the canal or other structures. The contract should reflect this uncertainty, allowing for some flexibility, which would facitilitate agreements on additional costs.

### 4.4.2 Management and Inspection of Construction Sites

Using the experience gained during the first years of the Project, both in the projects implemented by force account and those done by contract, construction management and inspection by EPU technical personnel appear to have been adequate. During visits to the sub-projects, it was observed that the inspectors and managers had the required abilities and experience. However, the support personnel, such as surveyors and assistants, are very young and lack sufficient experience in dealing with contractors, which has impeded agreement on quantities and the evaluation of payments and additional sums.

Another general problem that has affected both management and inspection is the inadequate system of communications between the offices and the construction sites and the lack of vehicles for transportation. These

two deficiencies noticeably reduce useful working hours and the effectiveness of supervisors and they contribute to increased costs and slower construction. In some cases, the supervisors rely on the contractors for their communications and transportation.

The AID Project Office, in support of the work of Electrification Project Units, periodically sends an engineer to visit the sites to discuss progress with the managers or inspectors and contractors, and also to interview future users in the service areas.

In addition, quarterly reports reflecting physical progress, investments, delays, accidents, etc. are prepared in Lima, based on data supplied primarily by the EPU. These reports are sent to the AID offices.

Additional technical and accounting supervision is provided by the Management Control Unit, which also sends its own technical personnel to the construction sites. This additional monitoring duplicates in many respects the supervision carried out by the Project Office.

### 4.4.3 Relations with Contractors and Manufacturers

In the first sub-projects, certain problems developed in the relations between ELECTROPERU and the contractors and manufacturers, because of differing interpretations of the contracts and conditions prior to commencing work.

These problems are gradually being overcome. At present the only remaining difficulties are with the civil works contractors, attributable primarily to design changes and claims for additional costs because of greater quantities or other contingencies, which are discussed elsewhere in this report.

### 4.4.4 Recommendations to Facilitate Construction Supervision and Implementation

a) Radio equipment and vehicles should be provided to site inspectors to facilitate their work and expedite sub-project implementation.

b) Some SHPP projects should continue to be carried out via force account, especially if the basic data are not very reliable. This procedure helps to maintain a general control of construction costs and to train internal personnel.

c) Another alternative would be for the consultant in charge of the design to supervise and control the construction, thus reducing the need for extreme detail in the designs. The construction contract could be based on unit costs (see Section 4.3.2). ELECTROPERU or the Regional Electric Companies would provide overall supervision, controlling quantities, payments and contract administration.

## 4.5 Use of Technical Assistance

The provision of technical assistance should have been a key component of the Project. However, technical assistance has not been used as expected, as described below.

### 4.5.1 Evaluation of the Technical Assistance Provided

The original funding contemplated in the Project Grant is outlined as follows:

| Objective | Amount in US$ |
|---|---|
| 1. Eight rural promoters of the productive use of electricity, during the first year of operation of each plant. 50% of the cost funded by AID. | 100,000 |
| 2. Advisor contracted for the duration of the Project, for development of personnel, monitoring Project implementation and preparation of pre-feasibility and feasibility studies. | 450,000 |
| 3. Energy economist to assist the OPAT (or its successor) in preparing a methodology and studies of demand and economic feasibility. | 80,000 |
| 4. Environmental impact analyst, as part of the feasibility study. | 40,000 |
| 5. Specialist in the design and construction of hydroelectric plants, to advise OPAT. | 60,000 |
| 6. Assistance to the OPAT or its successor in training rural promoters for a campaign to promote the productive uses of energy. | 40,000 |
| 7. Energy planner to assist OPAT in implementing a national small hydroelectric power plant program. | 60,000 |
| 8. Assistance to ELECTROPERU in developing a pricing, billing and collections policy. | 60,000 |
| 9. Specialist in maintaining hydroelectric plants to train four mechanics in preventive maintenance. | 40,000 |
| 10. Final Project evaluation by an economist, an engineer and a sociologist. | 40,000 |
| 11. Training program for four mechanics for preventive maintenance of the turbine-generator equipment, 50% funded. | 30,000 |
| Total | 1,000,000 |



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The technical assistance specified above was appropriately planned and was intended to ensure that the study, implementation, operation and maintenance of the Project's mini-hydro plants would make the best possible contribution to the development of rural electrification.

However, ELECTROPERU has not given technical assistance the same priority that it bestowed on other activities related to the preparation and construction of the SHPP. The continual changes in the institution's organization and the disappearance of the OPAT, as well as the decentralization process instituted by the General Electricity Law, have quite possibly reduced ELECTROPERU's attention to the technical assistance.

Until now, the technical assistance effectively provided amounts to only US$313,000. Several months ago, in view of the fact that ELECTROPERU had made little use of the funds, AID decided to fix the ceiling of the Grant at US$750,000.

Following is a summary of the technical assistance that has been provided or planned to date:

| Objective | Assistance Provided |
|---|---|
| 1. Expenses of rural promoters | Several video cassette tapes about electrification were produced and promotional activities were funded in Chongos Alto. |
| 2. General advisor | The advisor spent one year in Peru and partially fulfilled his mission. |
| 3. Energy economist | The work and recommendations of Arthur D. Little, Inc. were incorporated into the "AID Methodology" for the evaluation of sub-projects. Economist A. Fernández of the Project Office worked closely with the consultant's personnel in the development of this methodology. |
| 4. Environmental impact analyst | Two experts (one from the USA and one from Peru) prepared reports that provided basic information and were used as guidelines for preparing the final feasibility studies. An attempt to reach an agreement with ONERN for further research failed because of administrative problems in that agency. |
| 5. Standards and design specialist | The expert reviewed drawings, specifications and terms of reference for the procurement of equipment, recommended adjustments which were incorporated into the documentation, and evaluated the proposals for the equipment for Chongos Alto, as an example. |

| Objective | Assistance Provided |
|---|---|
| 6. Training of rural promoters | No assistance provided. |
| 7. Energy planner | No assistance provided. |
| 8. Assistance in rates and collections | Economist A. Fernández of the Project Office will attend a one-month course on Planning and Electric Power Rates. |
| 9. Maintenance specialist | No assistance provided as yet. However, in accordance with recommendations in this report, the development of a training program at ELECTROLIMA's technical schools, including visits from equipment manufacturer's experts, will be attempted. |
| 10. Final project evaluation | The preparation of this report fulfills the evaluation objective. |
| 11. Costs of training mechanics | No assistance provided as yet. See objective 9 above. |

As can be seen from this summary, of the eleven activities, only 3 and 10 above have been completed in their entirety, and 1, 2, 4 and 5 have been completed partially. The other five activities have not been addressed at all, although there are plans for implementing three of them (8, 9 and 11).

Also, on October 6, 1986, the Rural Electrification Department wrote AID requesting approval of a supplementary list of small scale assistance projects to complete the US$750,000 of the Grant. This supplementary list, approved by AID on November 6, 1986, includes the development of small industrial and agricultural projects, salaries for professional personnel in the AID Project Office and in the field, and other aspects of the promotion of productive uses of electricity, in addition to a microcomputer, radio transmitters, rental of vehicles, and studies. The studies included should be defined more clearly, and they should be completed quickly, in the short period of time left prior to the PACD (May 1987), so that they can fulfill the purposes for which they have been proposed. Part of the funds requested for studies could be used to finance the technical assistance recommended in other sections of this report for SHPP maintenance and promotion of productive uses of electricity (see Sections 6.4, 7.4, and 4.5.2).

### 4.5.2 Expected Technical Assistance Needs

Following are recommendations related to activities that could still be carried out and that would help reach the objectives of the technical assistance program:



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a) Get the Regional Electric Companies to take into account the conclusions of the environmental impact studies in the operation of the power plants.

b) Insist on technical assistance for the promotion of productive uses of electric power (see recommendations in Section 7.4).

c) Develop and implement a preventive maintenance training program for the small hydroelectric power plants, using classrooms and workshops at ELECTROLIMA's technical schools (see recommendations in Section 6.4).

d) Use four to six months of technical assistance to analyze and improve project management from the study phase through the startup of the SHPP (see recommendations in Section 4.1.4).

Should there not be enough time prior to the PACD to contract foreign experts, qualified assistance could be sought in Peru.

## 4.6 Coordination with Other Involved Institutions

After the General Electricity Law was promulgated in 1982, ELECTROPERU formed an Electrification Project Unit in each region and established the relationships between them and the Regional Electric Companies. The responsibilities assigned to the EPU included channeling requests for rural electrification, supervising the civil works and installation of equipment, and finally, the transfer of the completed power plants to the REC that will ultimately manage them. Recently, in accordance with the regionalization program adopted by the GOP, the EPU are being transferred to the REC, and they will no longer be dependents of ELECTROPERU.

### 4.6.1 Relations with the Regional Electric Companies

Through the site visits, it was confirmed that the relations with the Regional Electric Companies are good and that this has helped resolve many of the problems that are normally encountered in this type of work.

Prior to the transfer of the Electrification Project Units to the Regional Electric Companies, requests for electricity arrived either at the EPU or at the REC, via development corporations, municipalities, political officials, etc. They were then reviewed as a group and transmitted, via the EPU, to ELECTROPERU's offices in Lima, to be considered in the program for expansion of the national electric frontier. Now, the forwarding of requests will be performed entirely by the REC.

Another collaborative effort has taken place during the equipment installation stage. The REC have designated the technicians and operators who will work at the power plants when they are operational, enabling them to be present while the equipment is installed and familiarize themselves with its details, which should be of great value to them as they assume their jobs.

Once construction has been completed, the REC assume responsibility for management and maintenance. If something unexpected occurs during the warranty period, the contractors and manufacturers must cooperate in resolving the problem. If problems occur after the warranty period has expired, the REC (previously it was the EPU) must assume responsibility for solving the problems and covering the corresponding expenses.

As has been mentioned, it is the intention of the GOP to have the Electrification Project Units become part of the REC. In the case of the Trujillo EPU, the transfer agreement with the Regional Electric Company Electro Norte Medio HIDRANDINA S.A., was signed in August 1986. Similar agreements have been signed by the EPU and REC in other regions. As of this writing in early November, it is understood that several of the EPU (including those of Trujillo and Huancayo) have already been transferred to the corresponding REC.

A reading of the above-mentioned transfer agreement brings up several questions as to how the Electrification Project Units will be incorporated within the organizational structure of the Regional Electric Companies without impairing the experience nor the functional cohesiveness which has been developed within the EPU. Other concerns relate to how the REC will promote community support in the sub-project service areas and how they will assume the responsibility for the control and movement of funds designated for rural electrification, especially the Project funds, which by contract can be managed only by ELECTROPERU.

### 4.6.2 Relations with Other Institutions

The Rural Electrification Department maintains relations with several organizations, such as BANVIP, the departmental development corporations, mining companies, private banks, finance companies, savings cooperatives, etc.

The primary objective of these relations is to obtain the support of the institutions for two key activities. The first is helping future users of electric power to finance the secondary grids, hookups and interior wiring in their homes. The second, which has not yet been well developed, is helping users purchase small industrial equipment or household appliances so that they may use electric power productively.

During the visits to the sites, good support for rural electrification was found among local merchants, development corporations, mayors and other authorities, all seeking anxiously to resolve problems that arise.

The visit to Chongos Alto confirmed the interest of electricity users and that of the Regional Electric Company ELECTROCENTRO in establishing a locally owned company to manage the secondary networks and also to take over billing and collections.

Reports and recommendations on this topic have been prepared during visits by several experts including Myk Manon and James D. Lay (from NRECA) in October 1982 and Polidoro E. de Sao Tiago (IDB consultant) in April 1985.

### 4.6.3 Recommendations Concerning Institutional Relations

a) The implementation of the agreements transferring the Electrification Project Units to the Regional Electric Companies should, to the extent possible, maintain the integrity of the individual units, particularly those engaged in construction supervision, thus ensuring the best use of experience already acquired.

b) See recommendations c) and d) of Section 4.1.4.

c) It is recommended that the Rural Electrification Department review the reports and participate with the Ministry of Energy and Mines in the evaluation of the proposal to form a locally owned company in Chongos Alto, with the possibility that it serve as a pilot project for future applications.

## 4.7 ELECTROPERU's Capability to Carry Out Other Similar Projects

ELECTROPERU's recent experience in rural electrification based on small hydroelectric power plants can be summarized as follows: since 1980, 36 power plants have been built (including three from the Project); 92 other plants are in different stages of implementation (including seven from the Project); and, several packages including a total of approximately 90 power plant projects are being evaluated in quarterly reviews.

In other words, over 200 small hydroelectric power plant projects, in different stages of study and implementation, have passed through the technical offices of ELECTROPERU during a period of approximately seven years. That effort places Peru as one of the front-runners among Latin American nations in the promotion of rural electrification based on small hydroelectric plants. The highlighted results have been achieved despite a general scarcity of financial resources and despite a relatively young responsible institution (ELECTROPERU). The AID Project has made a significant contribution to these efforts.

Although during this period errors that have delayed project implementation have been committed, the success of the work that has been completed should be pointed out and noted. A team of professional and technical personnel, which constitutes ELECTROPERU's finest capital for facing the future of rural electrification, has been trained.

Consequently, when the problems encountered in the past (and indentified in this report) are corrrected, ELECTROPERU and its dependencies will be fully capable of implementing other similar projects.

# 5. CONSTRUCTION PROGRAM

## 5.1 Progress Achieved in Construction Work

As of the date of this report, three of the Project's ten sub-projects have been completed: Chongos Alto, Cajabamba and Pucará. The decision has been made to complete four of the remaining seven sub-projects prior to the extended Project expiration date (May 1987) using AID funds. The four are: Cutervo, Namora, San Marcos and Pachiza. The other three (Niepos, Celendin and Sorochuco) will be completed using only ELECTROPERU funds, except that in Niepos and Sorochuco, AID will fund the low voltage network and residential hookups.

Table 5-1 and Appendix 9 show progress achieved at the construction sites through mid-October, based on the physical progress achieved by contractors, as evaluated by ELECTROPERU. Of the four sub-projects whose civil works and equipment will be partially funded by AID, Pachiza is farthest from completion, with only 20% of the civil works having been finished. The progress in the civil works at Namora and San Marcos has been verified through site visits by the evaluation team.

In Namora, the contractor has prepared the platform for the canal and is almost ready to begin working on structures. The camp is well installed and construction materials are on site. However, several claims resulting from the amount of excavation and the design of the project have led to lengthy delays, and the contractor had suspended all work. The consultants were told that construction would begin again in October 1986. If this occurred, the contractor would be in a good position to continue working efficiently and meet the present schedule.

In San Marcos, the contractor has prepared most of the platform for the canal. Still to be completed are a few hundred meters of excavation in hard rock, a short aqueduct and a section less than 200 meters long where a tunnel not anticipated in the original design may be required. No decision has yet been made regarding this tunnel, nor have claims for additional excavation in rock and other extra work been resolved. Although work has not been suspended, it would appear that the contractor is not managing the construction very effectively. Labor relations are poor, and the workers complain that they have not been paid for several weeks. Relations between the contractor and ELECTROPERU are not good, and the discussion of the extra costs could be a very lengthy process. Access roads are in bad condition.

At all sites, inspection of the works and project management are difficult because the inspectors have neither vehicles nor communications equipment.

Appendix 10 compares actual costs with costs estimated in the final feasibility studies of the three SHPP which have already been completed.

## 5.2 Project Implementation Plan

Table 5-2 shows anticipated construction completion dates according to the most recent Project Implementation Plan (September 30, 1986) prepared by the Project Office in ELECTROPERU.

Based on the information in Table 5-1 and considering the rate of work to date and the observations made during the visits to two sub-project sites, it is believed that, except for Cutervo, the contractors will have difficulty meeting the implementation schedule of Table 5-2. Delays because of bad weather are inevitable as the rainy season approaches. San Marcos and especially Pachiza are very far behind schedule and, unless extraordinary measures are taken, their completion is projected for July 1987.

In addition to the target dates specified in the present Implementation Plan, Table 5-2 also shows the anticipated completion dates for the sub-projects if no special actions are taken to accelerate the work. These estimated dates are based on the time required to construct the two projects which have recently been completed, which was 25 and 22 months, respectively. Since at present there are no indications that the work is being done at a faster rate, there is no reason to anticipate construction periods of less than 18 months if special measures are not taken. Several actions which would shorten the duration of the construction phase are recommended in the next section.

## 5.3 Actions Needed to Achieve Goals

To complete the seven sub-projects still under construction prior to the PACD (May 19, 1987), the following actions are recommended:

a) Improve communications between the site inspectors and the offices of the EPU by supplying the Project with radio equipment and vehicles.

b) Improve and accelerate procedures for resolving claims for cost overruns.

c) If necessary and appropriate, consider completing a portion of the work by force account.

d) Request that contractors submit monthly updated schedules and a description of all the measures that they plan to take in order to complete the projects on time, so that ELECTROPERU's supervisory staff can determine the status of each sub-project at any time.

e) Prepare and update flowcharts of the most important activities, determine critical path activities and focus efforts on them.



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f) Set up longer and more flexible work periods and, if possible, work more than one shift.

g) Speed up the payment of contractors and, in special cases, provide advances when approval of a total payment could be delayed because of slow administrative procedures.

h) Speed up customs procedures so that equipment arrives at the sites as quickly as possible.

i) Rapidly complete the tendering, awarding and contracting process for the transmission line and distribution network contracts which are still pending.

TABLE 5-1

CONSTRUCTION PROGRESS TO DATE

| Sub-Project & Estimated Cost (US$000) | Installed Capacity (kW) | Status of Construction Work (% Completed) | | | |
|---|---|---|---|---|---|
| | | Civil Works | Hydroelec. Equipment | Penstock | Transmission Lines and Networks |
| Chongos Alto 2,476 | 1,000 | | Completed | | |
| Cajabamba 1,277 | 520 | | Completed | | |
| Pucará 892 | 400 | | Completed | | |
| Cutervo 2,269 | 1,200** | 90 | Will arrive site 12/86 | Completed | Stage 1 - 90% Stage 2 - 50% |
| Pachiza 1,015 | 400 | 20 | In customs | In factory 20 | 95 |
| Namora 1,456 | 600 | 40 | In customs | In factory 90 | 20 |
| San Marcos 1,337 | 330 | 50 | In customs | In factory 90 | 15 |
| Niepos 1,638 | 1,000 | 30 | En route | In factory 50 | Bids to be requested |
| Celendín 1,943 | 1,000 | 45 | En route | 0 | Bids to be requested |
| Sorochuco 542 | 230 | 55 | Awarding in process | 55 | Bids to be requested |

* Costs of Chongos Alto and Cajabamba are actual final costs. Costs of Pucará are estimated final costs, with sub-project accounting not yet completed. Costs for remaining projects are projected costs, as indicated in the latest revision of the Project Implementation Plan.

** Cutervo is being built in two stages, one of 800 kW and a second of an additional 400 kW.

Source: AID Project Office, ELECTROPERU. See Appendix 9.

TABLE 5-2

ESTIMATED SUB-PROJECT COMPLETION DATES

| Sub-Project | Estimated Completion Date: Current Project Implementation Plan* | Estimated Completion Date: Probable Date |
|---|---|---|
| Cutervo | December 1986 | February 1987 |
| Pachiza | May 1987 | July 1987** |
| Namora | March 1987 | March 1987 |
| San Marcos | March 1987 | July 1987** |
| Niepos | March 1987 | May 1987 |
| Celendin | April 1987 | June 1987** |
| Sorochuco | April 1987 | May 1987 |

* Source: AID Project Office, ELECTROPERU, Draft of Quarterly Report No. 16.

** Completion in May 1987 is possible if the recommended actions are implemented.

# 6. OPERATION AND MAINTENANCE OF FACILITIES

## 6.1 Institutional Focus on Operation and Maintenance

Responsibility for operation and maintenance (O&M) of the SHPP facilities rests with the Regional Electric Companies.

Whenever possible, operators are hired locally and provided with a house near the plant. Maintenance and repairs are carried out by a team of technicians who are also responsible for repair and maintenance of the diesel plants. The maintenance technicians are based in the headquarters and zonal offices of the Regional Electric Companies.

The Cajabamba power plant has sufficient personnel to operate the plant 24 hours per day. The personnel at Chongos Alto have not been stabilized yet, and the plant provides service only from 4:00 p.m. to 8:00 a.m.

When emergency repairs are required, the operator must notify the REC central office, from where a technician is dispatched to effect the repairs. This process could take several days, since communications from locations like Chongos Alto are very poor, and the operators must seek ground transportation to send a message to the central office. Spare parts inventories, which have been established according to manufacturers' recommendations, are located at the plant sites. At the power plants that were visited, manufacturers have supplied the necessary manuals for all installed equipment.

Training of the Regional Electric Companies' O&M personnel takes place at the power plants during the installation and testing of the equipment. Although the original Project Agreement had foreseen a more extensive program for training power plant O&M personnel, this has not taken place.

It would seem that since the operations and maintenance of the SHPP is not a direct responsibility of ELECTROPERU, personnel of that institution have shown little interest in promoting programs to reinforce O&M activities.

However, the Regional Electric Company ELECTROLIMA has two technical schools devoted to the training of operations and maintenance personnel. The Electrotechnical Training School has been operating since 1963, while the Mechanical and Hydraulic Technical School has been open since 1980. Both offer intensive twoto three-year courses which include classroom instruction as well as practical shop work. Graduates work primarily in ELECTROLIMA, but the schools have the capacity to train personnel for the other Regional Electric Companies as well. Because not enough jobs are available, some graduates have not been employed by ELECTROLIMA and would be available either to do O&M work for other regional companies or to train O&M personnel of those companies.

ELECTROLIMA could coordinate the use of the existing technical schools to train operations and maintenance personnel of the Regional Electric

Companies, making use of the funds that are still available for this purpose in the AID Grant.

## 6.2 Observed Deficiencies

During the visits to Cajabamba and Chongos Alto, the two plants which are already in service, several operations and maintenance problems which require attention were observed.

In Cajabamba water was being wasted, and the plant was being operated below its installed capacity for fear that the available water might suddenly fall below the level required to maintain the existing load. Communications between operators at the plant and at the canal are not adequate to solve this problem.

To optimize water usage during low flow periods, water level monitors can be installed in the forebay. Sometimes these monitors are connected to the governor via a control system in order to maintain the greatest generation possible during low flow periods. This objective can also be achieved by using an alarm to alert the operator when the forebay water level has dipped below the lowest acceptable level, allowing him to reduce the load on the turbine accordingly.

The access roads between the powerhouse and the intake works, canal and forebay, particularly in Cajabamba, should be maintained in a better condition in order to facilitate the operations involved in opening and closing gates, cleaning sand traps, etc.

The following are other general observations made during the visit to the Cajabamba SHPP:

a) There is no equipment for cleaning the forebay trash rack.

b) There is no emergency lighting at the power plant to be used in the event of a power outage.

c) The synchronization of the hydro and diesel plants was difficult, communications between the two plants were deficient, and the operators appeared to lack experience and knowledge of the equipment.

d) Drainage of the slopes above the canal is insufficient; as a result, runoff material enters the canal during rainy periods and is carried through the turbines, causing increased wear.

The visit to Chongos Alto resulted in the following general observations:

a) The forebay overflow channel cannot handle the total design flow in the event of a load rejection. In such a case, the intake or sand trap gates would have to be closed rapidly in order to avoid damage to the surrounding areas that would result from the overflow.

b) Communications between the powerhouse and the canal operator are nonexistent, complicating the problem described above.

c) The spaces between the bars of the forebay trash rack are too wide, which allows debris to enter the penstock. On one occasion, a branch was lodged in the turbine, which had to be taken apart to remove the branch.

d) A sheet of plywood which is on the verge of failure is being used as a flushing gate in the intake works to allow for the periodic cleaning of the intake. When the intake is full of material, removing the plywood is very difficult.

## 6.3 Measures Recommended to Improve Operations

To resolve the operational problems observed in the two plants which were visited, which could also occur in the other plants, the following measures are recommended:

a) Install a water level monitor in the forebay.

b) Purchase portable radio equipment, or something similar, to facilitate communications between the plant operator and the person in charge of the canal.

c) Foster a coordinated effort with local residents whose land is in the drainage area, and particularly with those who live near the intake and above the canal, to plant and reforest their property. This would help to prevent soil erosion, benefitting the power plant and providing agricultural benefits to the landowners.

d) In Chongos Alto, install a sheet metal gate or op-log barrier at the flushing gate. Regardless of the material chosen, smooth metal guides should be installed to facilitate removal of the gate or the logs. Portable equipment (which can be taken away to avoid damage during flood flows) should be used to remove and replace the gates. A portable jack or a block and tackle could solve the problem. Care should be taken to design the gate so that it can be easily removed during flood flows, when material must be cleared away from the intake works. (For example, heavy hooks or bars would be preferred to chains for attaching the removal mechanism--whether it is a jack or a block and tackle--to the gate.)

e) Provide first aid kits and fire extinguishers in clearly visible and easily accesible locations, to be available should there be an accident. (These items were not seen in the site visits.)

f) Add drainage ditches where needed to collect runoff water from the upper slopes, before it enters the canal.

g) Provide tools to remove stones from the canal and clean the trash racks.

## 6.4 Measures Recommended to Ensure Adequate Maintenance

Based on that which was observed during the visits to the Cajabamba and Chongos Alto plants, the following recommendations regarding maintenance of the SHPP are formulated:

a) It is essential to provide adequate training to operations and maintenance personnel to ensure that all repairs can be effected without unnecessary delays. It is important that plant operators understand the technology and are able to carry out at least minor repairs and all routine maintenance on their own.

   To that end, it is recommended that arrangements be made with ELECTROLIMA to establish, in the company's technical schools, a program for training operations and maintenance personnel of the Regional Electric Companies. Even though the training of the SHPP operators would probably continue beyond the PACD (May 1987), certain measures could be taken prior to Project completion to make use of available Grant funds. These include:

   - Visits by equipment manufacturers' experts to the technical schools, to train instructors in the operation and maintenance of the newly installed equipment.

   - Purchase of additional equipment to supplement the existing equipment in the school workshops, in accordance with the needs identified by the manufacturers' experts and by the schools' directors; and

   - Referring unemployed graduates of the schools to the Regional Electric Companies to fill operations and maintenance jobs permanently or to provide on-the-job training to SHPP operators.

b) Adequate communications, by radio or telephone, should be established between the power plants and the offices of the REC.

c) Access roads to the power plants should be maintained in good condition either by the REC or by the appropriate local governments.

d) Internal accesses to the intake works and the canal should be maintained in a condition that would allow the mobilization of equipment needed for major repairs (for example, a backhoe after a flood flow).

e) Facilities should have adequate tools on site. A determination should be made of what tools are needed, and these should be purchased and stored on site.

f) An adequate inventory of spare parts is essential. Domestic manufacturers should be encouraged to supply needed parts where possible. To that effect, standardization of equipment (e.g., control panels) would be very advantageous.

g) Ongoing maintenance of the civil works is important. Operating personnel should devote spare time to repairing concrete structures, cleaning and lubricating gates, repairing trash racks, etc. Based on observations during the visits to the power plants, it is anticipated that an almost continuous cleaning of the canals will be required to remove material that falls from the slopes above.

# 7. PROMOTION OF THE USE OF ELECTRIC POWER

## 7.1 Importance of Promotional Activities

The justification of the construction and operation of the SHPP is based on the economic and social benefits that are expected to be obtained from them. If the new subscribers do not make adequate use of the electric power available from the SHPP, the benefits expected from the investments will not be obtained and the potential value of the projects to the communities and the country will be lost. Actively promoting the use of electricity among the potential beneficiaries of the electrification helps to realize the benefits and, consequently, avoid losses.

Electric power has many uses which, for the purposes of this analysis, can be grouped into two major categories: residential uses and productive uses. The benefits of rural electrification come from uses in both categories, which implies that the promotional activities should encompass both productive and residential uses.

## 7.2 ELECTROPERU's Promotion Campaign

To date, ELECTROPERU's promotional work has concentrated primarily on the residential uses of electricity, apparently quite successfully.

### 7.2.1 Promotion of Residential Uses (Initial Promotion)

In each of ELECTROPERU's Electrification Project Units there is a group or a person in charge of promotion. (That group or person will be integrated into the corresponding Regional Electric Company.) Before the construction of the SHPP and the associated distribution lines is begun, the promotional units are responsible for registering potential users and inscribing them in a program for paying the costs of secondary networks and residential hookups, as required by the General Electricity Law. Sometimes, this job is shared with the Departmental Development Corporations.

In general, payments are made through loans granted by the Peruvian Housing Bank (BANVIP), which are amortized during the first five years after the SHPP become operational. The promoters are charged with explaining to the residents the benefits of electrification and the cost payment program. They must also collect from the residents the down payments required, which amount to 10 percent of the total costs.

To help the promoters in the diffusion of the advantages and the procedures for electrification, several video cassettes were recorded using AID Grant funds. The tapes covered the following subjects:

- "Rural Hydroelectric Power Plants" (14 min.);
- "Commitments Between Users and ELECTROPERU" (14 min.);

- "Financing the Electrification Project" (12 min.);

- "Rural Residential Wiring" (9 min.);

- "Preparation of Wood Power Line Posts" (9 min.); and

- "Uses of Electric Power" (10 min.).

The tapes have been shown at five of the ten localities that will receive power from the small hydroelectric power plants.

In general the tapes deal with the procedures to be followed when electric power is provided to a communaity, with emphasis on the residential uses of electricity. One of the videotapes (the last one in the above list) develops the theme that electricity should be used not just to illuminate houses, but also to facilitate productive work and ease daily chores.

### 7.2.2 Promotion of Productive Uses

Except for the preparation of the above-mentioned videotapes, ELECTROPERU has only recently shown any interest in the promotion of productive uses of electric power. Six months ago the Electricity Promotion Service (EPS) was formed within the Rural Electrification Department and charged with developing and implementing a program to promote the productive and rational use of electricity. The EPS has five professionals to carry out its responsibilities. To date, they have dedicated their efforts to tasks such as:

- preparation of a general work program;

- preparation of a specific work plan for the Department of Cajamarca;

- visits to several microregions, including Chongos Alto;

- coordination with several entities which could be involved in the promotion and implementation of small development projects, such as the Development Corporations, Regional Electric Companies, Ministries, the Agricultural Bank, the Industrial Bank, electrification committees, etc.;

- preparation of publicity materials (whose publication is awaiting funding); and

- drafting regulations for a National Committee for Rational and Productive Use of Electric Power, which would coordinate ELECTROPERU's actions in this area with those of the Regional Electric Companies.

The EPS staff has found a great deal of interest among potential productive users, as well as in the organizations that could assist in the electrification process, but so far no program leading to the effective

electrification of productive tasks in the communities has been implemented. To make the Electricity Promotion Service more effective, the following is required:

- support of the EPS by ELECTROPERU;
- technical assistance, especially relating to the identification, evaluation and justification of small projects involving the productive use of electricity;
- an additional budget for field work; and
- access of electricity users to sources of credit to finance the purchase of equipment and, in some cases, the extension of power lines to the workplace.

It should be noted that the Project Agreement contemplated technical assistance, in the form of an expert in the development of training programs, to help ELECTROPERU design and implement a program for training eight rural promoters who would have worked in the target communities during the first year of operation of each of the SHPP. In the original budget of the Grant, a total of US$100,000 was also set aside to fund half of the promotion campaign, including expenses incurred by the rural promotors. However, to date, this training has not been carried out, and no promoters have been deployed to do the field work contemplated in the Project Agreement.

## 7.3 Results of the Promotion Campaign

The promotion of the use of electricity has been successful in the registration of new residential customers for the small electrical systems. However, from interviews and visits to the SHPP communities, it can be concluded that there has been no real progress in the use of electric power for productive purposes.

### 7.3.1 Secondary Networks and Residential Hookups

In general there has been a high degree of acceptance of electrification by the communities where the SHPP are being built. Most of the residents have responded with enthusiasm and have made their initial payments without delay, although there have been cases in which the residents have preferred to wait and see the works being implemented prior to making any payments. Despite the fact that three of the contracts for the construction of secondary networks are still in the tendering process, it is understood that the users have fulfilled their obligations in a timely manner.

According to information obtained from the Trujillo EPU and the Regional Electric Company HIDRANDINA, the inscription of users in Cajabamba has proceeded much more rapidly than had been foreseen for the year 1986 in the feasibility study:

| | Cajabamba SHPP | |
|---|---|---|
| | Feas. Study | Actual |
| Number of housing units | 1,820 | 1,820 (estim.) |
| Electrification coefficient | 0.58 | 0.90 |
| Number of subscribers | 1,060 | 1,650 |

The subscribers include approximately 25 special customers (schools, clinics, public buildings, churches, etc.). Also included are seven productive users (carbonated drink factory, sawmills, grinding mills, etc.), although all of these existed prior to the construction of the SHPP, when they used their own generating equipment. The new Cajabamba power plant became operational at the end of September 1986. The plant's hydro power is supplemented by a thermal plant that for several years has supplied power during nighttime hours to a smaller group of users.

In the cases of the Namora and San Marcos SHPP, both still under construction, an incomplete presentation of intermediate results in the demand study prepared by the consulting firm has prevented a comparison of actual and forecast subscribers. Nevertheless, from the reports of the Electrification Project Unit, the following results as of October 3, 1986 can be seen:

| | San Marcos SHPP | Namora SHPP |
|---|---|---|
| Number of housing units (prefeasibility study) | 1,610 | 1,590 |
| Number of potential users (EPU data) | 1,770 | 1,500 |
| Number of polled users (EPU data) | 550 | 1,070 |

The Chongos Alto SHPP became operational in January 1986, supplying electricity to local communities for the first time. Data obtained from the Huancayo Electrification Project Unit and the Regional Electric Company ELECTROCENTRO reveal the following situation for 1986:

| | Chongos Alto SHPP | |
|---|---|---|
| | Feas. Study | Actual |
| Number of housing units | 1,890 | |
| Number of residential subscribers | 620 | |
| Number of commercial subscribers | 130 | |
| Total number of subscribers | 750 | 2,690 |

It is obvious that the number of communities presently served by the distribution network substantially exceeds the number foreseen in the feasibility study, explaining the high number of actual subscribers, which exceeds the number predicted for the year 2013.

In addition to subscribers who are already receiving electric power, the Huancayo EPU reported that a network expansion project currently being prepared would allow 1,600 more users to be served. To ensure the adequate supply of electric power, the interconnection of the Chongos Alto and Haurisca plants is being proposed.

The demand for power at the peak hour (19:00 hours) has reached 540 kW, compared with a maximum demand of only 220 kW forecast for the year 1986 in the feasibility study of the Chongos Alto SHPP.

The above figures reflect the fervent desire of the communities to have electric power in their homes and in public places.

### 7.3.2 Encouragement of Productive Uses

Of the ten SHPP encompassed by the Project, only Chongos Alto has been operational long enough to have been able to stimulate productive uses of electricity. However, not one case was identified in the service area in which electric power was used for other than a lighting or residential purpose.

There are at least three factors that contribute to the non-growth of productive uses:

- The power plant does not yet operate during normal working hours, being limited at present to a 4:00 p.m. to 8:00 a.m. schedule.
- The residents need some technical assistance, which they have not been able to receive, in order to identify and evaluate projects and to prepare loan applications.
- They also need financial assistance for the purchase of equipment and machinery.

Despite the present lack of productive uses in the service area, the residents have shown a great deal of interest in using electric power for such purposes. As a result of work done by ELECTROPERU's EPS and the local community organization, the latter has submitted to the EPS a list of productive activities that are of interest to each of the communities that presently have electric service. Technical and financial assistance for the implementation of several small electric development projects is requested.

In Cajabamba, conversations with an electrical appliance dealer, a cafe owner, the Mayor and the Manager of the Departmental Development Corporation also revealed a high degree of interest in the productive use of electric power, although this interest has not yet expressed itself in concrete actions. Although electricity is presently being supplied on a 24-hour basis, the short time the SHPP has been in operation is insufficient to have had a major impact on the service area's patterns of production.

The conclusion is that there has still not been an effective stimulation of productive uses of electric power in the Project service areas.

## 7.4 Recommended Measures for Promoting an Adequate Use of Electric Power

The actions suggested for promoting the productive use of electricity have as an overall objective the strengthening and preparing of ELECTROPERU's Electric Promotion Service, so that it can act as a catalyst of rural development based on a better use of electricity. Specifically, the recommendations are to:

a) Contract a rural development expert with experience in Latin America for four months, to train and work with EPS personnel in promotional studies and tasks such as the following:

- preparation of pilot feasibility studies of the most comme potential uses of electric power, in order to define indicators of viability which are easy to understand and apply, such as the number of cows necessary to justify a milking machine, or the amount of cultivated area that justifies an irrigation pump;

- determination of the requirements for obtaining loans from the Departmental Development Corporations, banks or other institutions, and the design and implementation of a program to assist users in the preparation of the required documentation;

- training of Electrification Project Unit and Regional Electric Company promoters by EPS personnel; and

- implementation of the other actions recommended below.

b) Prepare and distribute pamphlets and audio-visual tapes that demonstrate to farmers, carpenters, bakers, mechanics, etc. how they can increase production and income and/or reduce the number of hours they work by purchasing electrical equipment and using electric power.

c) Use Grant funds to cover the transportation and subsistence costs of EPS personnel and other promoters for time spent in the SHPP areas.

d) With the cooperation of the most capable and resourceful users, attempt to create model dairies, shearers and workshops which would demonstrate to other residents the advantages of using electricity.

e) Ensure that the small hydroelectric power plants supply electricity 24 hours a day.

Recommendations a, b and c could be implemented with Grant funds that have not yet been committed. The contracting of an expert in rural development (either foreign or Peruvian) would partially meet the technical assistance goal in promotional activities and would train personnel of ELECTROPERU, the Electrification Project Units, and the Regional Electric Companies.

## 8. FULFILLMENT OF THE PROJECT'S ROLE IN THE OVERALL STRATEGY OF THE AID MISSION

In 1980, when the Project Agreement was signed, two of the three principal components of the AID strategy in Peru focused on rural areas. These were:

- promotion of social programs in the Andean region; and
- development of agriculture, rural infrastructure and employment opportunities in the sierra and high jungle, in order to increase the income of the rural poor in those areas.

The strategy of the Mission was adjusted in 1984, resulting in three objectives similar to the previous ones:

- support of policies and programs that promote the rational use of resources;
- increasing the income and employment of low-income families in urban and rural areas; and
- expansion of the efficiency and the coverage of the delivery of social services.

In keeping with the above-mentioned rural development strategies, the objectives of the Project have been to improve the quality of life and to increase the productivity of the rural poor through the provision of electric power. The Project has also had the objective of improving ELECTROPERU's institutional capacity to develop, evaluate and implement SHPP and similar projects.

As discussed in detail elsewhere in this report, it is believed that the most important objectives of the Project have been achieved, with certain minor exceptions. Therefore, it is concluded that the Project has contributed directly to the attainment of the overall goals as expressed in the strategy of the AID program for the country.

It is estimated that approximately 18,000 rural families will enjoy the benefits of having electricity in their homes when the implementation of the 10 sub-projects is completed. The provision of electricity to schools, clinics and other social service centers will allow greater efficiency in the delivery of their services. The utilization of the water resources and the evaluation and selection of the sub-projects in accordance with their net benefits have contributed to the rational and efficient use of the country's resources. Finally, the training of ELECTROPERU personnel in the evaluation and implementation of the SHPP projects has advanced the institutionalization of those concepts.

One objective that has not yet been fulfilled as anticipated is the development of productive uses of electricity in the rural areas, another important element of the overall strategy of the AID Mission program. One reason is that permanent, around-the-clock electricity has not yet been available long enough to allow this development process to take place. However, an additional promotional effort will probably be required to achieve a significant level of productive use of electric power in the short term.

# 9. PROSPECTS FOR THE FUTURE DEVELOPMENT OF SMALL HYDROELECTRIC PLANTS

## 9.1 Development Priorities of the Government of Peru

The new Government has had to face serious economic and social problems that impede the country's development. These include an extremely high foreign debt, the centralization of economic and government activities in Lima, a deteriorated industrial sector, a high rate of unemployment, the stagnation of income and economic growth, and a terrorist movement that promotes social dissatisfaction. The problems are especially acute in the rural areas.

To overcome those problems, the Government has sought to encourage rural development, especially in the areas with the greatest poverty, decentralize the country's activities, reduce the bureaucracy, increase production in the agricultural sector, encourage national industry and restructure the distribution of income Special emphasis is placed on the development and improvement of the quality of life in the Andean region.

There is also an effort to motivate, help and prepare the inhabitants of the rural areas to resolve their own problems, without having to depend on a central bureaucracy that generally responds slowly to rural needs.

In the electricity subsector, the objectives and goals expressed in the 1986 Electricity Master Plan, include (among others) the following:

- intensify the systematic evaluation of the hydroelectric potential, with the objective of increasing and optimizing the hydro-generation of electricity, raising it from 78 percent of total production in 1985 to 92 percent in the year 2000;

- consolidate the endeavors of the Regional Electric Companies in order to secure decentralization and improve regional development;

- supply electric power to 61 percent of the country's population by the year 2000 (presently 40 percent have electric service); and

- increase the use of electricity in productive activities.

The 1985-1990 National Plan for Expansion of the Electric Frontier, which is updated annually as required by the General Electricity Law, calls for an increase in the degree of electrification in smalland medium-sized population centers from 17 percent in 1984 to 25 percent in 1990, thereby benefitting an additional population of approximately 1.3 million inhabitants.

In order to achieve the general development objectives, as well as the specific goals of the electricity subsector, the GOP has assigned a high priority to rural electrification.

The Government's support of rural electrification is expressed tangibly through the continuing appropriation to it of revenues from taxes on electric power consumption. The tax and the use of its proceeds are established by law.

## 9.2 Benefits of Small Hydroelectric Plants

The importance of rural electrification within the country's development priorities is easily appreciated. It facilitates social development, education, the delivery of health services, communications and the encouragement of productive activities in rural areas. It helps to create a better community environment and an expectation of future benefits that make rural life more attractive and tend to curb the migratory wave toward the large urban centers, thus aiding the decentralized growth of the country and the promotion of the agricultural sector.

The SHPP play an important role in rural electrification, especially in the communities located at some distance from the interconnected systems or from existing power plants. They offer several advantages over other sources of electric power. The advantages of the SHPP include the following:

- they are relatively easy to operate and mantain;
- they use renewable water resources and reduce dependency on petroleum;
- if engineered and built satisfactorily, they can offer electric power at a reasonably low cost, especially in comparison to thermal options or the extension of lines over long distances and/or difficult terrain;
- they provide opportunities for the development and support of a national industry to manufacture electromechanical and electrical equipment;
- the small magnitude of the works facilitates the involvement of regional entities (the Electrification Project Units and the Regional Electric Companies) in their construction, contributing to decentralization and regional development; and
- they offer greater security, as compared to large installations, through the geographic dispersal of energy sources.

## 9.3 Comparison with Other Sources of Electric Power

Because of the different approaches taken in the SHPP studies and the studies of larger projects, only an approximate determination of the relative economic viablity of the SHPP can be made based on information from studies available in ELECTROPERU. The "AID Methodology" for the economic evaluation of SHPP provides a benefit/cost ratio, but the studies of the larger projects covered by the Electricity Master Plan

focus only on determining the investment option that would satisfy the forecast demand at the lowest cost.

In addition, when considering projects for the extension of transmission lines from an interconnected network, to be able to compare their indicators of economic viablity with those of the SHPP, information is required not only on the cost of the transmission lines, but also on the cost of generating the energy that would be consumed. This last cost depends on the level of utilization of the available capacity. In the short term, only the marginal cost of generating the additional energy required, which is generally lower than the marginal cost of increasing the capacity of the system, should be taken into account. In the medium and long term, however, not only the cost of generation, but also the cost of additional capacity must be considered, since eventually the installed capacity will have to be increased. For the interconnected system in 1987, the Electricity Master Plan forecasts an excess capacity of only 18 percent over the peak demand, without considering a reserve margin, and an average annual growth of demand of approximately five ercent.

Despite these difficulties, the costs of the various sources of electric power have been compared, taking into account the costs of civil works, equipment, transmission lines and operation. The results of the comparison are the following (see details in Appendix 11):

| | US$/kW Installed | US$/Kwh Generated |
|---|---|---|
| 100 MW hydroelectric plants | 1,000-1,500 | 0.02-0.04 |
| Small hydroelectric plants | 1,700-3,000 | 0.05-0.08 |
| 50 MW thermal plants | 400-1,350 | 0.06-0.09 |
| Small thermal plants | -- | 0.08-0.10 |

The cost of a 10 to 20 kV transmission line is estimated at US$15,000 per kilometer. If the alternative to constructing an 800 kW SHPP were the extension of a transmission line over a distance of 40 km, for example, the transmission cost incurred would be approximately US$0.02 per kWh. The total cost of the alternative (in the long run) would be calculated by adding the cost of transmission to the cost of generating the power (including capital costs and operating costs).

## 9.4 The Role of Small Hydroelectric Plants in Electric Power Development

From the points previously raised, it can be concluded that the program for developing SHPP in Peru should be continued. The program is a very important component of rural electrification, to which the GOP has assigned a very high priority. When compared with the other possible sources of electric power, SHPP can supply electricity to isolated rural areas at reasonable costs. The SHPP projects are relatively easy to carry out, facilitating their implementation by the Regional Electric

Companies and contributing in this way to the goal of national decentralization. Their reduced size allows for rapid implementation and delivery of their benefits, in accordance with the country's ability to finance them, without requiring users to await the lengthy erection of a major facility. The SHPP also take advantage of renewable natural resources and reduce the country's dependence on petroleum, which are also important goals of the Government.

## 10. SUMMARY OF PROJECT SUCCESSES

Despite the problems and delays the Project has encountered, some of which are attributable to its implementation during a period of restructuring and decentralization of the national government as well as of ELECTROPERU and the Regional Electric Companies, several significant successes have resulted from the efforts dedicated to it. These are summarized below:

a) Ten small hydroelectric plants and their associated distribution networks will have been built, at reasonable costs and within reasonable time periods, permitting the delivery of electricity to some 18,000 families in rural areas of the country.

b) The development of a national private industry capable of manufacturing electromechanical and electrical equipment for SHPP has been stimulated and supported, which should reduce the costs of future projects and increase their net benefits to the national economy.

c) ELECTROPERU's staff has been trained in the preparation, evaluation and implementation of SHPP projects. However, there is some danger that the experience gained could be lost as discussed in Section 11.2.

d) A methodology for the economic evaluation of SHPP projects has been implanted in ELECTROPERU. However, even though the projects are evaluated using this technique, to ensure that the advantages of the use of the methodology are realized, the criteria for the selection of projects to be included in the National Plan for Expansion of the Electric Frontier will have to be modified (see Section 11.2).

e) As a result of the use of the economic evaluation methodology in this Project, sub-projects with adequate economic benefits have been selected and implemented, thus contributing to the rational use of the country's resources.

f) The interest of rural residents in furthering the development of rural electrification with the help of ELECTROPERU has been verified and encouraged, as has their desire to contribute toward the betterment of their own standard of living.

Through the construction of the SHPP, the Project has contributed significantly to achieving an important government objective, the improvement of the standard of living in rural areas of the country. For this reason, it is considered that the Project has been well focused and has fulfilled its primary purpose.

As a result of the experience ELECTROPERU has gained in the implementation of the sub-projects and other similar works, the capability of the country to make rational use of its water resources has been demonstrated, and international financial institutions and other friendly countries have indicated an interest in a possible cooperation in the development of future rural electrification projects.

# 11. SUMMARY OF DEFICIENCIES AND RECOMMENDED ACTIONS

## 11.1 Failures and Problems that Require Immediate Attention

Although the Project has achieved some degree of success in the construction of the SHPP, there are still some problems and failures that could delay the completion of the work and/or affect ELECTROPERU's ability to implement similar projects in the future. Following is a summary of the failures and problems of the first type as well as recommendations for overcoming them. Devoting immediate attention to these situations will facilitate the timely and successful completion of the Project.

a) Very little effort has been dedicated to promoting the productive use of electricity. The training in this area that was called for in the Project Agreement has not taken place.

   Recommendation: Contract an expert in rural development for approximately four months to train and work with personnel of ELECTROPERU's recently created Electricity Promotion Service, assisting them in implementing several measures designed to promote the productive use of electric power among residents of Project service areas.

b) Attention has not been given to training personnel of the Regional Electric Companies to operate and maintain the SHPP. The technical assistance that had been foreseen for this purpose has not been used. However, it is important to ensure that the operators possess all the knowledge necessary for a continual and safe operation of the SHPP.

   Recommendation: In collaboration with ELECTROLIMA, use ELECTROLIMA's technical schools to train personnel of the Regional Electric Companies in the operation and maintenance of the SHPP. In the short term, and using available Grant funds, bring in experts from the manufacturers of the new electromechanical equipment for short periods of time to train the school's instructors; purchase certain new equipment to supplement existing equipment in the schools; and send unemployed graduates of the schools to the Regional Electric Companies either to accept permanent jobs or to provide on-the-job training to the SHPP operators.

c) The efficiency of the work of the on-site construction inspectors suffers greatly because of a lack of means of communication and transportation. This deficiency has resulted in unnecessary delays and cost increases and in a reliance on the contractors for those services.

   Recommendation: Acquire radio equipment to allow for immediate and direct communications between on-site inspectors and the offices of the Electrification Project Units (or the Regional Electric Companies). Likewise, rent or purchase vehicles for the inspectors' use until construction has been completed.



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d) The construction of several of the sub-projects has been delayed as a result of the slow procedures used to resolve contractor claims.

Recommendation: Take extraordinary measures to accelerate the analysis of claims for extra work and the approval and payment of the corresponding amounts, resorting to solutions such as the following:

- contracting the additional personnel required in the Project Office;

- providing mobility to Project Office personnel;

- establishing special procedures that would permit the approval of payments for additional work without having to resort to the General Manager or the Directors of ELECTROPERU; and/or

- paying advances in anticipation of the approval of the additional sums in question.

e) The slow progress being achieved in some of the sub-projects will not permit their completion prior to the Project Assistance Completion Date (May 19, 1987).

Recommendation: In special cases, consider supplementing the work of the contractors who are furthest behind with work administered under force account. Require the contractors to increase their personnel, equipment and working hours and to keep their work plans up to date.

f) The transfer of the Electrification Project Units to the Regional Electric Companies, which is currently in progress, could lead to delays in the supervision of the sub-projects and in the approval and disbursement of payments to the contractors.

Recommendation: Seek a way to avoid changing the personnel and procedures that are already established in the Electrification Project Units for supervising and controlling sub-projects and handling Project funds during the remainder of the Project's life.

g) Project funds have not been handled expeditiously. A current balance of approximately US$900,000 has been disbursed by AID but has not yet been accounted for by ELECTROPERU.

Recommendation: Expedite the final accounting for completed projects, the payment of pending invoices and the updating of the corresponding accounting records.

## 11.2 Failures and Problems with Longer Term Solutions

In addition to the problems requiring immediate attention, several problems and situations that have made the preparation and implementation of SHPP projects difficult have been identified within ELECTROPERU.



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Although resolving these problems would no longer affect the timely completion of the Project nor the successful achievement of its immediate goals, the correction of the deficient situations could facilitate the implementation of future projects and agreements, as well as the improvement of ELECTROPERU's future endeavors. The primary problems and recommended solutions, which are discussed in greater detail in the preceeding sections of this report, are:

a) ELECTROPERU has inadequately supervised the preparation of studies and designs by the consulting firms, with the consequences that are pointed out below.

   Recommendation: Implement a stricter supervision of the consulting firms in the future, especially with regard to obtaining and using field information, design concepts and standardization, and the identification of potential construction problems.

b) The consulting firms generally prepared their studies and designs at a level of detail which is not justified given the usually scant and unreliable basic data on hydrology, topography and geology. Likewise, the designs are unnecessarily complex and lack uniformity.

   Recommendation: Strive for simple and flexible designs, using standardized designs whenever possible, thereby facilitating the adjustments necessitated by the actual conditions encountered as the works are implemented.

c) The lump sum construction contracts are drafted and interpreted too rigidly, which hinders the adjustments which are inevitable in projects of this type because of the usually inadequate data on sub-soil and topographical conditions.

   Recommendation: Make contracts more flexible, emphasizing fixed unit costs and flexible quantities, always under the control of the site inspector, so that the contracts can be adapted to the real conditions found at the sites, without the need to resort to so many claims that delay the projects.

d) The tendering, awarding and contracting process is too slow and complex.

   Recommendation: Facilitate the process by taking measures such as allowing approval of awards and contracts at lower decision levels than the present ones. All the procedures of the process, and especially those that relate to the selection of the winning bidder, should be reviewed and revised.

e) Insufficient attention has been given to providing maintenance equipment and tools to the SHPP.

   Recommendation: Provide the SHPP with a complete set of the equipment and tools necessary for efficient operation and maintenance,

including means of communication (radio or telephone) between the plants and the zonal offices of the Regional Electric Companies.

f) The plants have been observed to operate sometimes at a level that does not take full advantage of the available water flow, for fear that the flow could suddenly fall below the level required to maintain the load.

Recommendation: Install water level monitors in the forebays with the ability to actuate an alarm in the powerhouse if the water level should fall below a specified level.

g) Certain defects in the hydraulic governors at the plants that are already in operation have been noted. It has not yet been determined what type of regulator is the most appropriate for this type of SHPP in Peru.

Recommendation: Investigate the advantages of the various types of governors presently available, specify the most advantageous type and arrange for it to be manufactured locally.

h) In general, the SHPP were designed to use a flow of water that would be available 90 percent of the time. However, some of the SHPP will work in conjunction with a thermal plant, while others may be joined to an interconnected grid in future years. In such cases, a greater design capacity might be appropriate.

Recommendation: Consider and evaluate alternatives of greater design flows in cases such as those mentioned above. Also, where the minimum flow rate is specified with great uncertainity, evaluate designs that would facilitate the future expansion of the SHPP at a reasonable cost, devoting special attention to the capacity of the canal.

i) There is a risk of losing personnel trained in construction implementation and supervision because of the transfer of the Electrification Project Units to the Regional Electric Companies. There is also a concern about the future of trained personnel in the Project Office once the Project ends.

Recommendation: Take steps to ensure that the Electrification Project Units are transferred as integral units, thereby taking advantage of the experience and ability of each person as well as of the personnel as a whole. Also take prompt steps to assure skilled personnel in the Project Office that their employment will continue after the Project Agreement expires, and try to keep the staff together in a similar activity related to the planning and control of SHPP projects. Four engineers and one secretary have already left their posts. Permanent positions should be offerred to the present contract employees, both in the Electrification Project Units and in the Project Office, with the appropriate salary adjustments.



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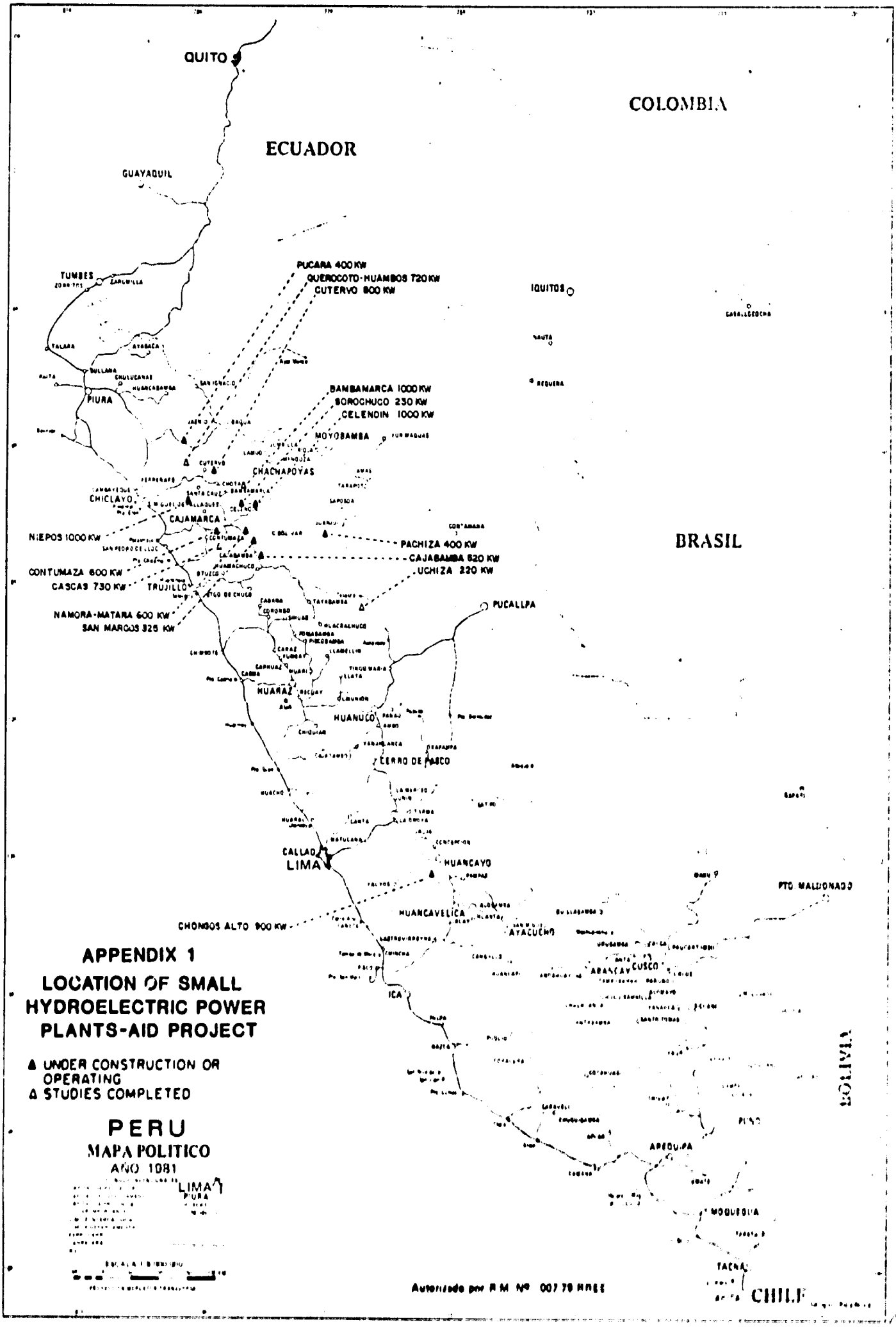
j) Several vacant positions in the Rural Electrification Department, especially at the unit head level, interfere with the fulfillment of the duties of this entity.

Recommendation: Assign personnel to the vacant posts, or replace the positions with another with the responsibility of assisting the department manager, in order to achieve a better coordination of efforts and a greater availability of information.

k) Although the selection of the sub-projects implemented under the Project has been based on benefit/cost ratios calculated according to the economic evaluation methodology developed in the Project, that criterion is not applied universally in ELECTROPERU for the selection of projects to be included in the National Plan for Expansion of the Electric Frontier .

Recommendation: Revise the procedure for selecting SHPP projects, making the benefit/cost ratio the primary criterion for assigning priorities. Also review the economic evaluation methodology, using the experience gained to date and the data available from the sub-projects which have already been completed, especially in relation to cost and demand, with the objective of adjusting and refining the methodology as appropriate.

# APPENDICES


QUITO
COLOMBIA
ECUADOR
GUAYAQUIL
TUMBES
PUCARA 400 KW
QUEROCOTO-HUAMBOS 720 KW
CUTERVO 800 KW
IQUITOS
PIURA
BAMBAMARCA 1000 KW
SOROCHUCO 230 KW
CELENDIN 1000 KW
MOYOBAMBA
CHACHAPOYAS
CHICLAYO
CAJAMARCA
NIEPOS 1000 KW
PACHIZA 400 KW
CAJABAMBA 520 KW
UCHIZA 220 KW
BRASIL
CONTUMAZA 600 KW
CASCAS 730 KW
TRUJILLO
NAMORA-MATARA 600 KW
SAN MARCOS 325 KW
PUCALLPA
HUARAZ
HUANUCO
CERRO DE PASCO
CALLAO
LIMA
HUANCAYO
PTO MALDONADO
CHONGOS ALTO 900 KW
HUANCAVELICA
AYACUCHO
ABANCAY
CUSCO
ICA
BOLIVIA
AREQUIPA
MOQUEGUA
TACNA
CHILE
APPENDIX 1
LOCATION OF SMALL HYDROELECTRIC POWER PLANTS-AID PROJECT
▲ UNDER CONSTRUCTION OR OPERATING
△ STUDIES COMPLETED
PERU
MAPA POLITICO
AÑO 1981
LIMA
PIURA
Autorizado por R M Nº 007 79 RREE

## APPENDIX 2

## LIST OF PERSONS INTERVIEWED

Agency for International Development (AID)

| | |
|---|---|
| Mr. Donor M. Lion | Director |
| Mr. George Hill | Assistant Director |
| Mr. Mark Silverman | Chief, Office of Development Resources |
| Mr. Edilberto Alarcón | Chief, Engineering and Implementation Division |
| Mr. Alfredo Larrabure | Project Coordinator |

Empresa Pública de Electricidad del Perú (ELECTROPERU), Lima

| | |
|---|---|
| Mr. Emilio Chaparro Chaparro | Construction Manager |
| Mr. Oswaldo Morán Márquez | Manager, Rural Electrification Department |
| Mr. Benjamín Ibarra | Head, AID Project Office |
| Mr. Juan Rojas Ramos | Head, Management Control Unit, Rural Electrification Department |
| Mr. Hernán Bustamante | Head, Rural Electrification Unit, Technical Division |
| Mr. Antonio Fernández Cáceres | Economist, AID Project Office |
| Mr. Ernesto Napravnik | Engineer, AID Project Office |
| Mr. Hugo Meza | Accountant, AID Project Office |
| Mr. Pedro José Belleza | Cartographer, AID Project Office |
| Mr. Lincoln Tuesta Valverde | Head, Electricity Promotion Service, Rural Electrification Department |
| Mr. Adler López Huilca | Head, BANVIP Agreement Service, Rural Electrification Department |
| Mr. Juan Mata La Cruz | Former Head of OPAT and the Hydraulic Generation Office |
| Mr. Rafael Hospina | Head, United Kingdom Project Office |
| Mr. Werner Hess | Head, Technical Mission from the Federal Republic of Germany |
| Mr. Jorge Tapia Pacheco | Former Head, Federal Republic of Germany Project Office |
| Mr. Sixto Zegarra | Head, Planning Office, Rural Electrification Department |
| Mr. Jorge Saito | Procurement and Contracting Office, Rural Electrification Department |
| Mr. Pablo Ferradas | Head, Hydraulics and Dams, Technical Division |
| Mr. Ismaél Aragón | Chief Equipment Engineer, Planning Division |
| Mr. Amadeo Carrillo | Engineer, Planning Division |

ELECTROPERU, Electrification Project Unit (EPU), Truillo/Cajamarca

| | |
|---|---|
| Mr. Julio López Carriedo | Chief |
| Mr. David Dias Mautino | Head of Electricity Promotion |
| Mr. Miguel Camacho | Head, Coordinating Office, Cajamarca |
| Mr. Carlos Alva León | Head, Accounting |
| Mr. Telésforo Ruiz | Inspector, Cajabamba |
| Mr. José Mulanovich Iquain | Site Inspector, San Marcos |
| Mr. Juan Cruz Aguilera | Site Inspector, Namora |
| Mr. Eleazar Ríos Huerta | Engineer |
| Mr. Pablo Salazar Cossio | Engineer |
| Mr. Carlos Rosas Marroqui | Engineer |

ELECTROPERU, Electrification Project Unit (EPU), Huancayo

| | |
|---|---|
| Mr. Juan Rodriguez | Chief |
| Mr. Juan Ruiz | Engineer/Inspector |
| Mr. Luci Calderón Cuyutupa | Works Coordinator |
| Mr. Jorge Manrique Arana | Promoter |

Ministry of Energy and Mines

| | |
|---|---|
| Ms. Carmen Monge | Director General of Electricity |
| Mr. Raúl Noriega Ezcurra | Director General, General Planning Office |
| Mr. Luis Llanos | Director, Electricity Planning Office |
| Mr. Néstor Vargas Céspedes | Electricity Advisor, Office of the Minister |
| Dr. Félix Pacheco L. | Energy Advisor, Office of the Minister |
| Mr. Ciro Zúñiga G. | Electricity Advisor, Office of the Minister |
| Mr. Percy León | General Directorate of Electricity |

Regional Electric Company Electro Norte Medio HIDRANDINA S.A.

| | |
|---|---|
| Mr. Alfredo Paiva | Commercial Manager |
| Mr. Edilberto Campos R. | Chief, Cajamarca Zone |
| Mr. Julio Salas Gallegos | Head of Operations and Maintenance, Cajamarca |
| Mr. Bermúdez | Head of Marketing, Cajamarca |

Regional Electric Company ELECTROCENTRO S.A.

| | |
|---|---|
| Mr. Alejandro Guisse M. | General Manager |
| Mr. Juan Carlos Neira S. | Operations Manager |
| Mr. Eduardo Cárnac Cuba | Head, Maintenance Unit |
| Mr. Teódulo Basualdo Quiquia | Marketing Unit |

Regional Electric Company ELECTROLIMA S.A.

| | |
|---|---|
| Mr. José Antonio Villena | Director, Technical Schools |
| Mr. Miguel Stucchi | Director, EFET |
| Mr. Agustin Farjo | Director, ETEMHI |

Others

| | |
|---|---|
| Mr. Guzmán Aguilar de Ancos | Assistant Representative, IDB |
| Mr. Luis A. Silva Tejada | Resident Engineer, Cáceres Construction Company, San Marcos |
| Mr. Florencio Porta Lozano | President, Central Committee for Electrification of the Canipaco Zone and President of the Board of Directors, Multicommunity Hydroelectric Company of the Canipaco Zone |
| Mr. José Rosell Castillo | Mayor of Cajabamba |
| Mr. Marcos Centurión | General Manager, Departmental Development Corporation of Cajamarca |
| Mr. Reyes | Head, Handicraft Center, Chongos Alto |

APPENDIX 3

PRINCIPAL DOCUMENTS REVIEWED

AID, "Convenio de Proyecto entre la República del Perú y los Estados Unidos de América para Desarrollo de Pequeñas Plantas Eléctricas", 24 de noviembre de 1980.

AID, "Project Paper--Small Hydro Development, Perú", Project NO. 527-0226, 1980.

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Alboric, e.i.r.l., "Proyecto San Marcos-Ichocán, Estudio Definitivo", Vols. I-VI, 1984

Alboric, e.i.r.l., "Proyecto Central Hidroeléctrica Namora-Matará, Estudio Definitivo, Evaluación Económica", Vol. V, 1984.

ELECTROPERU, Oficina del Convenio AID, "Informe Trimestral USAID-13, Oct. Nov. y Dic. de 1985".

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ELECTROPERU, Servicio de Promoción Eléctrica, "Elaboración Plan de Trabajo-Promoción Productiva Dpto. de Cajamarca", agosto 1986.

ELECTROPERU, "Programa de Electrificación Provincial, Distrital y Rural; Convenios Internacionales".

ELECTROPERU, "Metodología de Prefactibilidad o de Factibilidad".

ELECTROPERU, Oficina del Convenio AID, "Metodología AID para Pequeñas Hidroeléctricas--Formulación de Estudios de Factibilidad".

ELECTROPERU, Oficina del Convenio AID, Planos de Proyectos de Cajabamba, Chongos Alto, Namora y San Martín.

ELECTROPERU, Organigrama de la Sub-Gerencia de Electrificación.

ELECTROPERU, Convenio con el Reino Unido, III-Reunión-1986.

ELECTROPERU, Convenio Reino Unido, "Programa Priorizado de los Proyectos del Convenio Reino Unido".

ELECTROPERU, Gerencia de Operaciones, Evaluación y Control de Gestión, División de Estadística, "Padrón y Estado de las Unidades de Generación, Centrales Hidroeléctricas Hasta 10 MW", 31 de octubre de 1986.

ELECTROPERU, Gerencia de Obras, Sub-Gerencia de Electrificación, Unidad de Control de Gestión, "Informe de Evaluación de la Ejecución Presupuestal de la Sub-Gerencia de Electrificación al 30.09.86", octubre de 1986.

HIDRANDINA, "Transferencia UPE Trujillo de ELECTROPERU a HIDRANDINA S.A.", agosto 1986.

Instituto Nacional de Planificación, "Sistema de Planes de Desarrollo 1986-90--Proyecto: Plan del Trapecio Andino, Caracterización de la Problemática", febrero 1986.

Instituto Nacional de Planificación, "Proyecto Plan Nacional de Desarrollo a Mediano Plazo 1986-1990", enero 1986.

M.Manon, "Informe Preliminar de la Cooperativa de Canipaco".

MEM, "Reglamento Ley General de Electricidad", D.S. 031-82 EM/VM.

MEM, "Ley General de Electricidad", mayo 1982.

## APPENDIX 4

## SMALL HYDROELECTRIC POWER PLANTS IN PERU

| First Year of Service | Installed Capacity (kW) 0-100 In Oper. | 0-100 Out of Oper. | 0-100 Total | 101-1,000 In Oper. | 101-1,000 Out of Oper. | 101-1,000 Total | Over 1,000 Total |
|---|---|---|---|---|---|---|---|
| Not Specified | 1 | 1 | 2 | | 1 | 1 | |
| 1907-1939 | 1 | 1 | 2 | 1 | 2 | 3 | 2 |
| 1940-1959 | 12 | 12 | 24 | 4 | 3 | 7 | 1 |
| 1960-1969 | 28 | 17 | 45 | 11 | 1 | 12 | 2 |
| 1970-1979 | 2 | | 2 | 6 | | 6 | 2 |
| 1980-1986 | 9* | 3 | 12 | 23** | 1 | 24 | — |
| Total | 53 | 34 | 87 | 45 | 8 | 53 | 7 |

Total, 0-10,000 kW:

| | |
|---|---|
| Operational | 105 |
| Out of Service | 42 |
| Total Built | 147 |

* Includes six completed projects not yet officially transferred to the Regional Electric Companies.

** Includes ten completed projects not yet officially transferred to the Regional Electric Companies.

Sources:

- ELECTROPERU, Operations Division, Management and Evaluation Control, Statistics Unit, "Padrón y Estado de las Unidades de Generación, Centrales Hidroeléctricas Hasta 10 MW", October 31, 1986
- ELECTROPERU, Construction Division, Rural Electrification Department, Management Control Unit, "Informe de Evaluación de la Ejecución Presupuestal de la Sub-Gerencia de Electrificación al 30.09.86", October 1986.

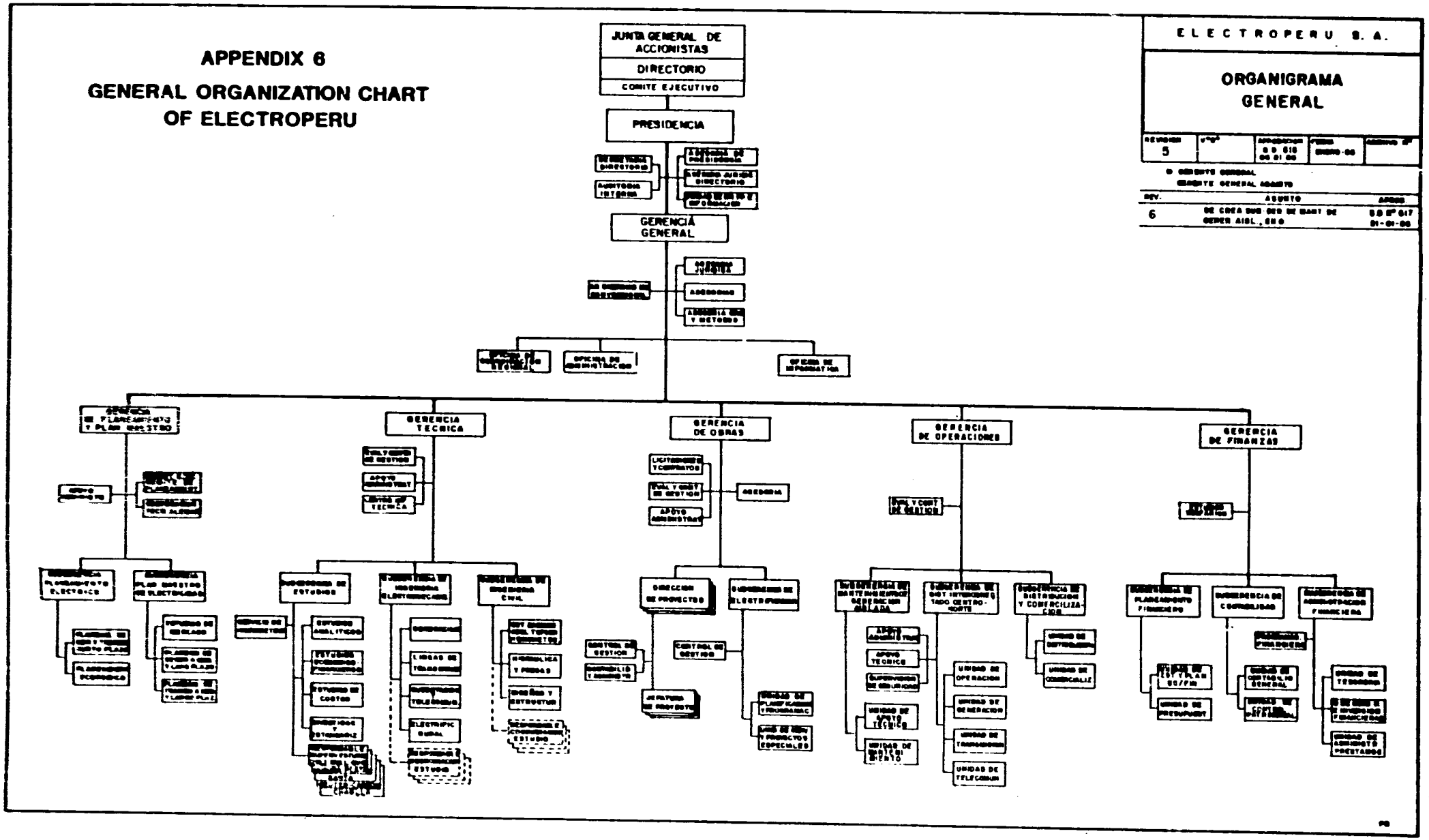
APPENDIX 5

SMALL HYDROELECTRIC POWER PLANT PROJECTS IN PROGRESS WITH EXTERNAL FUNDING

| | Capacity (kW) | Population (Inhab.) | No. of Plants |
|---|---|---|---|
| International Agreements (financing several categories) | | | |
| AID Agreement (technical assistance, studies, civil works, equipment, transmission lines, grids and training) | 6,680 | 125,000 | 10 |
| Fed. Rep. of Germany Agreement (technical assistance, studies and equipment) | 2,110 | 15,200 | 4 |
| United Kingdom Agreement (technical services and equipment) | 42,000 | 436,800 | 21 |
| Sub-Total | 50,790 | 577,000 | 35 |
| Other Foreign Contracts (financing only equipment) | | | |
| Chinese Equipment | 2,604 | 66,700 | 14 |
| SERCENCO Equipment | 4,250 | 97,600 | 4 |
| Brazilian Equipment | 660 | 31,500 | 3 |
| Sub-Total | 7,514 | 195,800 | 21 |
| TOTAL | 58,304 | 772,800 | 56 |

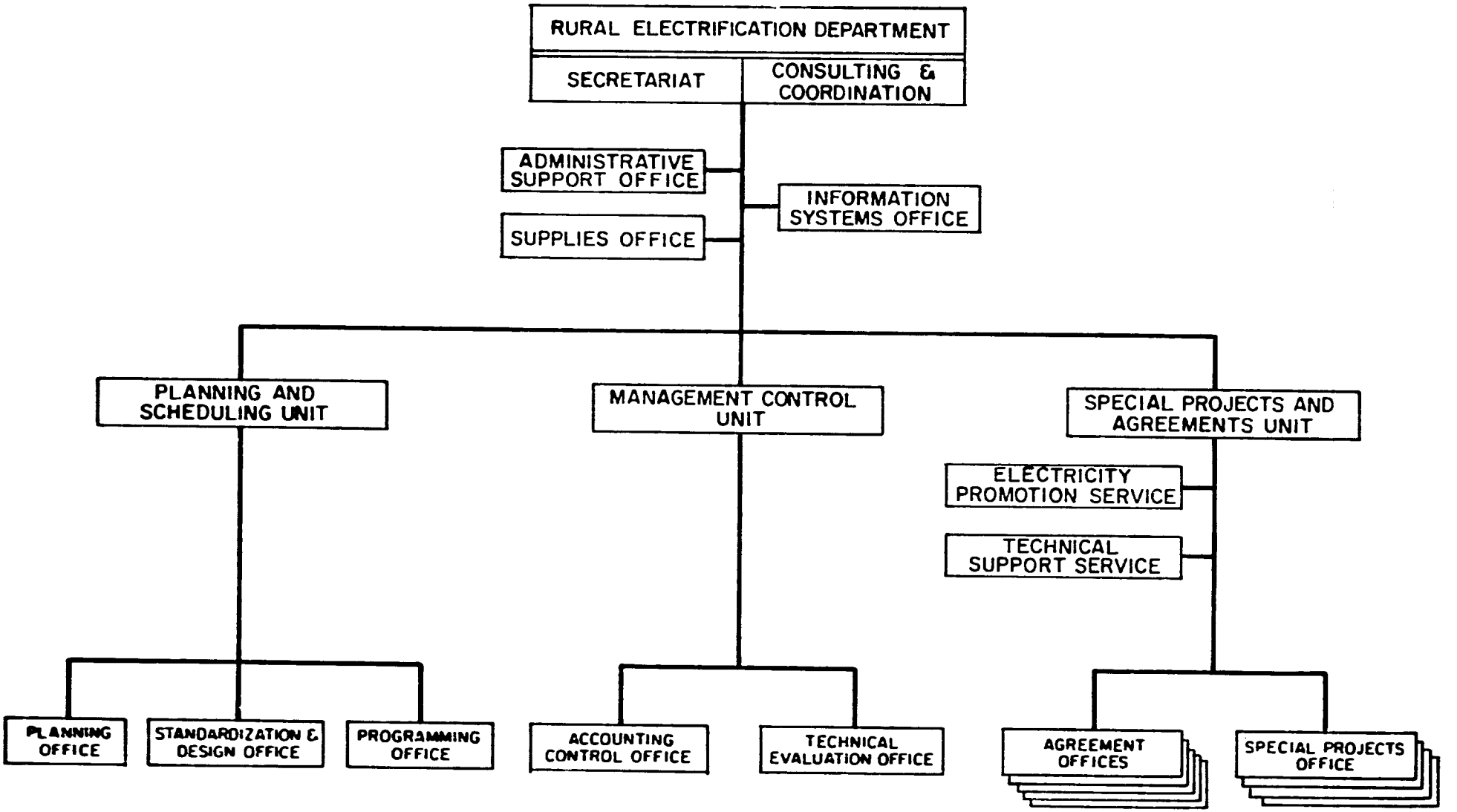
# APPENDIX 6

## GENERAL ORGANIZATION CHART OF ELECTROPERU



## APPENDIX 7

## ORGANIZATION CHART OF THE RURAL ELECTRIFICATION DEPARTMENT



## APPENDIX 8

### DESCRIPTION OF THE "AID METHODOLOGY" FOR THE ECONOMIC EVALUATION OF SUB-PROJECTS

The "AID Methodology" is the name given in ELECTROPERU to the methodology for the economic evaluation of the SHPP sub-projects. The methodology was developed and used in ELECTROPERU by the Office of the AID Project for the Development of Small Hydroelectric Power Plants. The evaluation is performed from a national point of view.

For a given sub-project, the methodology seeks to forecast, for each year of the planning horizon, the gross benefits that would be obtained, as well as the total costs to the nation of producing those benefits. Gross benefits include the benefits derived from the resources assigned to the sub-project (i.e., the value of the electric power to be produced, including consumer surplus), as well as the benefits obtained from alternate uses of the resources freed or displaced by the sub-project (such as the income that would be received from the export of diesel fuel which would otherwise be used to generate electricity in an existing thermal plant).

The costs include the costs of constructing the power plants, their annual operating costs, and the costs of the displaced resources. The costs and the benefits are expressed at their real economic values (i.e., at their shadow prices), which sometimes differ from market prices, such that adjustment factors must be applied to convert market prices to shadow prices.

To determine the benefits, which are based on the value of the energy consumed, the existing use of energy must first be analyzed in order to forecast the consumption that would exist were the sub-project not to be implemented. This analysis is carried out by surveying residents of the proposed service area. As a result of the analysis, forecasts of consumption are obtained, and based on the shadow prices of the different forms of energy, the cost per equivalent kWh is calculated.

The forecast of electric power consumption with the sub-project is based on several equations (expressed graphically) that have been formulated from an analysis of the demand for electric power in a few communities which are already served with electricity. The equations yield an electrification coefficient (percentage of homes served with electricity) as a function of time, as well as the unit consumption as a function of the number of subscribers. These estimates, together with a forecast of the number of housing units in the service area, lead to projections of demand for residential use and public lighting. To arrive at total consumption, the following must be taken into account: commercial demand, obtained from the number of commercial subscribers per residential subscriber; unit commercial demand, previously specified according to type of locality; and industrial demand, based on information obtained from the survey.

The gross benefits for each year consist of the total value that the displaced sources of energy would contribute in other sectors of the economy, the value of the electric power that would be consumed, at its shadow price (estimated at US$0.06/kWh), and the value of the consumer surplus, which reflects the total value that subscribers would have been willing to pay for the consumption of the same amount of power at prices higher than the above-mentioned shadow price. The consumer surplus is calculated from four values: the quantity of energy substituted (energy consumption without the sub-project), consumption of power with the sub-project, the price per equivalent kWh of the quantity consumed without the sub-project, and price per kWh of the quantity consumed with the sub-project.

The market costs of the resources assigned to the sub-project are determined in the technical study. Annual operating and maintenance costs are estimated via an equation that expresses costs as a function of installed capacity (in kW). The costs of the displaced resources are also included. All market costs are converted to opportunity costs (at the appropriate shadow prices).

After forecasting benefits and costs, three indicators of economic viability are calculated: the internal rate of return, the net present value, and the benefit/cost ratio. The latter two indicators are calculated at discount rates of 8%, 12% and 15%, considering the lowest to be the closest to the social discount rate. The assignment of implementation priorities to the sub-projects is based on the three economic indicators, in addition to the cost per installed kW and the cost per kWh consumed.

The methodology also calls for a comparison of the costs of the SHPP with the costs of a thermal power plant, assuming that both alternatives would produce the same benefits.

APPENDIX 9

PRESENT STATUS OF PROJECTS

OCTOBER 27, 1986

| MICRO-REGIONES | OBRAS CIVILES | EQUIPO HIDROELECTRICO MONTAJE Y PRUEBAS | SUMINISTRO TUBERIA DE PRESION | TRANSPORTE Y MONTAJE TUB. PRESION | LINEAS Y REDES ELECTRICAS |
|---|---|---|---|---|---|
| (1) CHONGOS ALTO 1000 kw | INICIO ABRIL 82<br>TERMINO JUNIO 86<br>POR ADM DIRECTA | Instalado.<br>INICIO JULIO 85<br>TERMINO AGOSTO 85 | Instalado.<br>CONCLUIDO | Ejecutado. | INICIO JUNIO 85<br>TERMINO JUNIO 86 |
| (2) CUTERVO 1200 kw | En construccion por ADM DIRECTA<br>Avance :95 %<br>INICIO JUNIO 84 | Fabrica : USIMEC del Brasil.<br>Gener.y Tablero:100 %<br>Entrega de Turbina en ENERO 1987 | SIMA : Terminado | COHISA : ejecutado. | I ETAPA:Contrato con CCPESA. Avance: 90 %<br>INICIO NOVIEMBRE 85<br>II ETAPA:Contrato con COVISA. Avance :50 %<br>INICIO ENERO 86 |
| (3) CAJABAMBA 520 kw | Construccion por ADM DIRECTA<br>Avance :100 %<br>INICIO MAYO 84<br>TERMINO JUNIO 86 | MULTITRADE: Instalado<br>Avance :100 %<br>INICIO JUNIO 86<br>TERMINO JULIO 86 | SIMA : Terminado. | COHISA : ejecutado. | COSAPI : Ejecutado.<br>INICIO DICIEMBRE 85<br>TERMINO MARZO 86 |
| (4) PUCARA 400 kw | BRUCE : Construido<br>Avance :100 %<br>INICIO ENERO 85<br>TERMINO OCTUBRE 86 | ALGESA : Instalado.<br>Avance :100 %<br>INICIO AGOSTO 86<br>TERMINO SETIEMBRE 86 | BRUCE :Ejecutado. | BRUCE :Ejecutado. | CANEPA TABINI :<br>Ejecutado.<br>AVANCE 100%<br>INICIO OCTUBRE 85<br>TERMINO MAYO 86 |
| (5) PACHIZA 420 kw | CACERES :En construccion.<br>Avance :20 %<br>INICIO FEBRERO 86 | BRAILLARD :Francia<br>Equipos en la Aduana<br>aduana Callao-Peru<br>Avance :85% | SIMA:fabricacion de tramos rectos.<br>Avance :20 % | Caceres : Incluidos en las O. Civiles | CIEMSA : avance 95 %<br>INICIO ENERO 86 |
| (6) NAMORA 580 kw | HUARCAYA-V.GUTIERREZ<br>En construccion<br>Avance :40 %<br>INICIO NOV 85 | BRAILLARD :Francia<br>Equipos en la Aduana<br>aduana Callao-Peru<br>Avance: 85% | SIMA : Avance 90 % | HUARCAYA-V.GUTIARREZ :<br>Incluidos en las O. Civiles. | ELNECO S.A :se firmo contrato el 07.05.86<br>avance :20 %<br>INICIO JUNIO 86 |
| (7) SAN MARCOS 330 kw | CACERES :En construccion.<br>Avance :50 %<br>INICIO ENERO 86 | BRAILLARD :Francia<br>Equipos en la Aduana<br>Callao-Peru<br>Avance :85% | SIMA : Avance 90 % | CACERES :Incluido en las O. Civiles. | SOPEN-BM :se firmo el contrato el 30.06.86<br>Avance : 30%<br>INICIO JULIO 86 |
| (8) NIEPOS 1000 kw | LAOS y BOLZMAN :En construccion.<br>Avance :30 %<br>INICIO ENERO 86 | ARMFIELD :Reino Unido<br>Fabricacion :100 %<br>En transporte al Peru | SIMA : Avance 50 % | LAOS Y BOLZMAN :<br>Incluido en las Obras Civiles. | Estudios terminados<br>Se encuentra por licitar. |
| (9) CELENDIN 1000 kw | COUSA :En construccion.<br>Avance :45 %<br>INICIO ENERO 86 | ARMFIELD :Reino Unido<br>Fabricacion :100 %<br>En transporte al Peru | COUSA :Incluido en Obras Civiles.<br>Avance :0 % | COUSA :Incluido en Obras Civiles. | Se encuentra en preparacion la Documentacion Tecnica. |
| (10) SORCHUCO 230 kw | CACERES :En construccion.<br>Avance :55 %<br>INICIO ENERO 86 | Licitacion : por resolver Otorgamiento de la Buena - Pro ( ALGESA ) | SIMA : Avance 100 % | CACERES :Incluido en las O. Civiles. | En proceso de licitacion. |

Fuente : Oficina Convenio A.I.D.

## APPENDIX 10

## COMPARISON OF ACTUAL COSTS WITH ESTIMATED COSTS

For the three sub-projects which have been completed, the following is a comparison of actual costs with the estimated costs presented in the Final Feasibility Studies. In each case, the latter costs were taken from the "General Project Summary" volume. The actual costs of Chongos Alto and Cajabamba were provided by the AID Project Office as the final construction costs of those sub-projects. The actual costs of Pucará are not final costs but are estimates of expected final costs prepared by the Project Office, since the sub-project final accounting has not yet been completed.

| | Construction Costs (US$000) | | | | | |
|---|---|---|---|---|---|---|
| | Chongos Alto | | Cajabamba | | Pucará | |
| Item | Study | Actual | Study | Actual | Study | Actual |
| Civil works | 546 | 953 | 678 | 712 | 390 | 475 |
| Equipment | 442 | 209 | 504 | 206 | 212 | 187 |
| Transmission lines | 428 | 570 | 127 | 132 | 97 | 58 |
| Distribution networks | 1,012 | 744 | 594 | 227 | 396 | 172 |
| Total | 2,428 | 2,476 | 1,903 | 1,277 | 1,095 | 892 |

In the case of Chongos Alto, the actual cost of the civil works includes the value of work contributed in kind by the beneficiaries of the SHPP, estimated at US$81,000. The Final Study for Chongos Alto did not provide estimates for the costs of transmission lines and distribution networks; these were taken from the official budget for the tendering of the works. In all cases, the cost of equipment does not include customs duties.

In general, the civil works have resulted in greater actual costs, in comparison with estimated costs, while the electromechanical equipment costs have been lower than budgeted. The costs of the distribution networks have also been less than expected. The cause of this last situation has not yet been determined, although it could have resulted because part of the distribution networks were financed by non-Project sources.

## APPENDIX 11

### COMPARISON OF COSTS OF DIFFERENT SOURCES OF ELECTRIC POWER

| Project | Installed Capacity (MW) | Cost in US$/kW Installed | Cost of Power (US$/kWh) | Benefit Cost Ratio |
|---|---|---|---|---|
| **Large Hydroelectric Power Plants** | | | | |
| Expansion of Cañón del Pato | 65 | 945 | .018 | |
| Jicamarca I (with reservoir) | 104 | 951 | .042 | |
| Mayush I | 100 | 1,485 | .035 | |
| Platanal | 99 | 1,583 | .030 | |
| **Large Thermal Power Plants** | | | | |
| Turbovapor - residual 6 | 50 | 1,352 | .062 | |
| Turbogas - diesel 2 | 50 | 368 | .092 | |
| **Small Hydroelectric Power Plants**** | | | | |
| Chongos Alto | 1.0 | 1,732 | .050 | 5.0*** |
| Cajabamba | 0.52 | 2,019 | .059 | 1.5 |
| Namora | 0.60 | 1,827 | .059 | 1.5 |
| San Marcos | 0.33 | 2,840 | .081 | 1.4 |

* Source: Electricity Master Plan, 1986, Table 5.3.

The costs per installed kW include costs of transmission lines between the power plant and the interconnected grid. In general, these lines are relatively short and represent a small part of the total cost.

** The cost indicators are calculated on the basis of the following costs and assumptions:

| | Estimated Costs (US$000) | | | |
|---|---|---|---|---|
| | Civil Works | Equipment | Transmission Lines | Annual Operation |
| Chongos Alto | 953 | 209 | 570 | 50 |
| Cajabamba | 712 | 206 | 132 | 32 |
| Namora | 610 | 353 | 133 | 46 |
| San Marcos | 615 | 212 | 110 | 27 |

Useful life: civil works, 50 years; equipment and lines, 30 years.

Discount rate: 12 percent.

An average load of 60% of installed capacity is assumed.

APPENDIX 11 (continued)

Source of costs: AID Project Office, ELECTROPERU. Chongos Alto and Cajabamba, actual costs according to the final accounting. Namora and San Marcos, estimated costs in the latest revision of the Project Implementation Plan.

The cost of civil works in Chongos Alto includes a contribution of communal labor valued at US$81,000. Costs of equipment do not include customs duties.

*** Benefit/Cost ratios, from the point of view of the national economy, including costs of distribution networks, were taken from the final feasibility studies for the SHPP. In the case of Chongos Alto, the ratio does not take into account the costs of transmission lines or distribution networks.

## APPENDIX 10

## COMPARISON OF ACTUAL COSTS WITH ESTIMATED COSTS

For the three sub-projects which have been completed, the following is a comparison of actual costs with the estimated costs presented in the Final Feasibility Studies. In each case, the latter costs were taken from the "General Project Summary" volume. The actual costs of Chongos Alto and Cajabamba were provided by the AID Project Office as the final construction costs of those sub-projects. The actual costs of Pucará are not final costs but are estimates of expected final costs prepared by the Project Office, since the sub-project final accounting has not yet been completed.

| | Construction Costs (US$000) | | | | | |
|---|---|---|---|---|---|---|
| | Chongos Alto | | Cajabamba | | Pucará | |
| Item | Study | Actual | Study | Actual | Study | Actual |
| Civil works | 546 | 953 | 678 | 712 | 390 | 475 |
| Equipment | 442 | 209 | 504 | 206 | 212 | 187 |
| Transmission lines | 428 | 570 | 127 | 132 | 97 | 58 |
| Distribution networks | 1,012 | 744 | 594 | 227 | 396 | 172 |
| Total | 2,428 | 2,476 | 1,903 | 1,277 | 1,095 | 892 |

In the case of Chongos Alto, the actual cost of the civil works includes the value of work contributed in kind by the beneficiaries of the SHPP, estimated at US$81,000. The Final Study for Chongos Alto did not provide estimates for the costs of transmission lines and distribution networks; these were taken from the official budget for the tendering of the works. In all cases, the cost of equipment does not include customs duties.

In general, the civil works have resulted in greater actual costs, in comparison with estimated costs, while the electromechanical equipment costs have been lower than budgeted. The costs of the distribution networks have also been less than expected. The cause of this last situation has not yet been determined, although it could have resulted because part of the distribution networks were financed by non-Project sources.