ELECTRICITY SUPPLY TO RURAL AREAS OF ARGENTINA

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Electricity Supply to Rural Areas of Argentina

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This report is an edited version of two reports by the same authors entitled Methodology of Appraising Alternatives for Electric Supply in Rural Areas, Case Study: Misiones Province, Argentina, 1988, and Electricity Provision to Rural Areas: The Diffusion of Hydroelectrical Micro Power Plants. Final Report, 1989.

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Introduction

Provision of electric energy to the rural inhabitants of developing countries is a prerequisite in any regional planning which seeks to improve rural quality of life and production levels. Providing electricity to regions located away from the urban centres and having dispersed population with very little ability to pay is one of the most difficult requirements to meet. Under these conditions, numerous rural electrification programmes carried out over the last decades by extending networks from the closest urban centers have had very poor results. At the same time, several technological development programmes obtained satisfactory results on energy conversion which could help solve the problem of rural electricity supply. However, the mass use of these technologies poses serious implementation and subsequent maintenance problems.

On the initiative of the International Development Research Centre of Canada (IDRC) in 1984 an international research programme known as RETAIN (Rural Energy Technology Assessment and Innovation Network) was conceived to throughly understand how to ensure the successful dissemination of new technologies for the rural supply of energy in its different end applications.

A number of case studies were carried out in several countries with experience in energy conversion alternative technologies applied to the rural sector. In each of the countries local research groups were organized. In Argentina the RETAIN Project was devoted to analyzing the experience in Misiones Province regarding the use of hydroelectric micro-power plants for supplying electricity to rural inhabitants by means of small decentralized systems. The Instituto de Economia Energetica (IDEE) was called upon to join RETAIN and coordinate the local programme activities.

Since using new sources and alternative technologies to provide energy to depressed rural areas strongly depends on government decisions, IDEE proposed to develop an electricity supply planning and evaluation methodology to provide the solid technical and economic arguments on which to base decisions.

The first stage of the RETAIN project in Argentina showed:

- Micro-hydro plants could effectively reach 36% of the 5,800 potential users identified in the study area.
- This level of supply could be provided by 90 micro-hydro plants which would supply 1,748 KW of installed capacity at a capital cost of US$5,585,965 (including distribution lines).

- The micro-hydro alternative is the most capital-intensive of the decentralized systems, with capital costs accounting for 90% of the total cost of the electricity supplied (assuming a time horizon of 10 years and an 8% discount rate).
- The cost of electricity supplied by micro-hydros is highly sensitive to variations in the load factor and the rate of discount. If the load factor is increased to 0.45 the cost per KWh falls to US$0.08 and the Equivalent Annual Cost is changed by 15% for every percentage point change in the discount rate (about 8%).
- The research demonstrated that micro-hydros have a large impact on macro-economic variables such as the local value added and the use of local labour.

The results of the evaluation study and the successful construction and operation of a significant number of demonstration units laid the foundation for formulating an expansion plan for Hydroelectrical Micro-Power Plant (HMPP) use which would complement the rural electrification programme in Misiones.

IDEE proposed carrying out a second stage of the RETAIN project in Argentina to formulate a normative plan for incorporating the HMPP into the Misiones electricity supply programme. This plan would be based on a previous diagnosis derived from the examination of the rural users' characteristics, rural electrification experiences already carried out, the development situation of the HMPP (the legal, institutional and financial aspects), and an accurate determination of the size of the market which could be supplied by the technology.

This volume contains reports of the first and second stages of the RETAIN project in Argentina. It explains why neither technical reliability nor economic competitiveness have been adequate conditions for undertaking the mass use of HMPP in Misiones; it also discusses dissemination strategies for this technology.

This study is related to a decentralized electricity supply technology supported by both private interests and the public sector. For private interests, it solves needs of a different nature. In the former case, it will be an alternative solution within a menu of options to be offered to potential users who show a 'solvent demand', and its market penetration will be supported by competitive conditions (reliability, price, financing, after-sales service). For the public sector, activity generally related to direct or indirect government action to promote the application of this alternative technology is as an instrument of scientific, economic or social development policies. It is a question of how to supply electricity to users having little or no ability to pay in response to their energy needs (expressed through the requirements) and not only to the solvent demand.

In the case of the HMPP in Argentina, the technological development was not part of a global planning process wherein research and development constituted a subprogram within a general solution for providing energy to the rural sector. Its origin and primary development have been from isolated decisions in the scientific field and with the impulse caused by enthusiastic researchers. This has caused much inconvenience regarding its insertion as an acceptable supply option into the governmental ambits and levels where energy sector decisions are made.

In Misiones the technological development stage (strongly related to the research and development sector) included the participation of numerous governmental and private institutions. This implied ten years of work and financial input of about two million dollars until completing the adjustment of the HMPP technology. During the first period, government support was very scarce and activities were based at Misiones University, with progress being made on the installation of family-scale pilot units. During a second period, government support increased with the participation of the Energy Secretariat and the province's Ministry of Public Works thus allowing researchers to set up, organize and operate multifamily-scale HMPP.

The outcome was that while a group of researchers had the know-how of a supply option which they considered of great use for solving the electricity supply to large rural areas in the region, those who made the decisions regarding the supply considered the HMPP a mere academic pastime of researchers and engineering students.

The development of the RETAIN Project, in its first phase, was to build a bridge between the planning sector and the new technology availability. Discussion at meetings and seminars analyzed the competitiveness in terms of public investment decisions and of HMPP against several other electricity supply options. It was no longer a question of just having a reliable technology but one which was also competitive against other options, including those conventionally used.

Another underlying problem which is common to every technological solution concerns supplying electricity requirements to rural people who have little or no ability to pay. The efforts made in Misiones over a decade show the disappointing result of having supplied only 10% of the rural inhabitants, most of whom belong to the high income level. Such limited results are due to technical/economical and financial reasons. Among the former there are those derived from applying criteria, in the out-fitting and building of the network extension, which favour quality over costs. Consequently, a feedback process occurred in which the resulting high costs of the works discouraged users and reduced the number of people who decided to be connected to the networks. This, in turn, caused a reduction in user density per kilometer of line and further increased the unit cost per user. The financial causes are due to lack of previous evaluation of user payment and repayment ability for 100% of the investment costs. These included adjustment and interest rates (on an inflationary economic background) which exceeded the increase in farming prices. During the first five years of credit amortization, the rural producers paid instalments which in terms of farming products (the index of their income) were three times as large as those estimated when they joined the plan.

Consequently, the first firm political decision regarding supply of an alternative energy technology to depressed rural areas is the financial requirement. This requires income mechanisms and financial strategies which cover the gap created between the minimum cost needed for meeting the requirements and a limited contribution from the beneficiaries. Accordingly, the supply financing plan should be made up of a non-returnable fund component (the funds deriving from the income transfer) and a returnable component, but the repayment conditions should be suited to rural producers' actual means.

Thus, the first basic conditions which will make the propagation of an alternative technology viable, in the absence of a solvent market demand, are the following:

- The political decision to meet the rural people's energy requirements made with full awareness of the costs and benefits implied;

- The technical decision to plan the supply of energy requirements incorporating the alternative technology in its corresponding field;
- The formulation of supply plan charges and financial strategies in accordance with beneficiaries' ability to pay.

The income transfer mechanisms operating in the electricity sector may be direct, such as setting-up 'special funds' derived from taxes imposed on other social sectors. Alternatively, indirect mechanisms, such as applying tariff structures which, instead of reflecting the costs incurred by each user in the system, generate cross subsidies among different use categories may be used. Cross subsidies are typical of electricity markets in which residential users (both urban and rural) with little ability to pay are serviced.

It was detected in the case study that low-consumption rural users share in the costs in a much larger proportion than they do in the income of the distributing companies. The magnitude of cross subsidy has been estimated as US$250 per rural user per year. A strong balance was detected in the final destination of the non-repayable investment funds since 85% are directed to large generation and to the national interconnection system. This means that the non-repayable funds derived from national savings are used for the benefit of the most developed electricity markets. Only 15% of the investment funds are used in generation, subtransmission and distribution works in the provincial jurisdictions. In Misiones, such scanty funds are not sufficient for distribution; hence 100% of the costs of extensions and connections, both rural and urban, are paid by users.

In order to correctly formulate the financial strategies accompanying the use of alternative technologies in the supply plan, it will be necessary to clearly diagnose the availability, origin and appropriation of the electricity sector investment funds. It is also necessary to explain and quantify the subsidies operating in the present forms of electricity supply and to accurately measure the potential user's payment ability. On this basis, the decision-makers will be able to adjust their criteria for applying the investment funds and directing the cross subsidies and other forms of assistance operating in the sector, in order to solve the supply financing plan.

The political decision to supply energy requirements presupposes three potential conflicts. The first is opposition to re-organizing the destination of the sector investment funds originating both in the national companies exploiting the large electricity generation and transmission systems and in the large private contractor firms which are the suppliers of these systems. Secondly, there is opposition to incorporating a new technology; this is expressed by the technical decision-making levels of the local companies rendering the electrical service. Thirdly, the workers' union is opposed to adopting decentralized and self-management forms of energy supply because they see their sphere of activities reduced.

The first opposition appears to be the most difficult to remove since national level decisions are required in a setting showing a strong disproportion between those who wish to introduce changes (poor provinces and rural organizations) and those who wish to maintain the present fund destination situation (large public and private corporations). The other two forms of opposition have been partially solved during the consultation process carried out in the RETAIN project studies. The local attitude has been one of favouring the purpose of improving the rural producers' living conditions rather than trying to preserve sector or personal positions. The plan to expand the HMPP within the rural supply has been formulated as a complement of network extension as regards its geographical delimitation, and as a transition as regards its temporal delimitation. Both conditions will make it easier to remove the local oppositions.

Development banks and the international agencies may contribute in solving the strong financial constraints present in these programmes for energy supply to marginal rural areas. As regards development banks, the need must be underlined for adapting credit granting criteria and policies so that they become real and significantly important finance sources for the most depressed areas. In this respect, it is not reasonable for regional development banks to use similar selection criteria and parameters for large energy production projects as they do for small marginal user supply projects. Although these are services which may be commercialized at a price covering the costs, those put at the disposal of the potential user or directed to meeting social needs may only be fulfilled if the price bears relation to the available income of users. For this reason development bank 'soft' credit, at rates similar to those fixed for social development projects, will speed up the process for the fulfilment of the rural inhabitants' 'right to energy'.

Once the basic political, technical and financial conditions have been met, foundations can be laid for the mass use of the new technology. Furthermore, the supply plan should be supported by institutional and organizational strategies which will ensure its success both in the execution and use stage.

In the case of the HMPP in Misiones Province two matters have come up representing new situations within the traditional modes of execution and exploitation of electricity supply works. The first refers to the technological risk associated with the presence of equipment and services not available at present in the market. This situation comprises the manufacturing and subsequent maintenance service of the turbines and frequency regulators. It is necessary to devise a quality assurance programme which covers rating and development of potential users as well as the conditions for the acceptance or rejection of supplies. The second refers to the management risk to be faced with a decentralized organization in which part of the HMPP operation and maintenance responsibility is passed on to the users themselves. Any idealization concerning the participative attitude of rural people must be avoided; social evaluations should define the assistance and training programme required for ensuring an efficient operation of the small decentralized systems.

The organizational structure adopted for dissemination depends on the nature of the activity involved and on the local participants. In the case of the HMPP in Misiones, hydraulic works have been designed as multi-purpose works with electricity supply being uppermost, followed by water for household and farming consumption, for industrial activities, for breeding fish and for recreation purposes. The activities derived from the plan have been defined as 'social and economic development ones with multiple purposes', and they involve the participation of several technological, social and economic disciplines. This definition is foreseen in the *Ley de Aguas* (Water Act) in force in Misiones Province.

Management efficiency during the pre-investment and investment phases is connected with a high degree of centralized activity with the participation of multidisciplinary teams made up of technicians and social workers from different organizations grouped in a special Execution Unit. During the exploitation phase, the follow-up and technical assistance activities may again be disaggregated per speciality and be attended to by different organizations in a decentralized way but always with a Coordinating Unit to channel the requirements derived from the application of the new technology.

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Background to the Case Study

Particular features of electricity demand in rural spheres, especially its low density and the low or zero payment capacity of the users, have restricted penetration of the centralized electric energy (potential) supply systems. As regards non-conventional means based on new sources and alternative technologies which could become a suitable solution to this problem, they have not reached significant levels of diffusion. This is due to a large extent to the scant confidence which policy-makers concede to these alternative solutions, even though they have gone beyond the technological development stage, and field demonstration units can frequently be encountered. This situation can be changed through the development of integral studies which would incorporate the non-conventional technologies as a valid alternative of electrical supply for the region subject to development planning. In this way analysis of the penetration possibilities of the new sources and alternative technologies generates a solid basis for decision-making and allows opening up the way to juridical, institutional, financial, negotiating and other transformations which would facilitate the mass diffusion to these technologies.

Within this context, in July 1985 the Institute of Energy Economics (IDEE) of Argentina and the International Development Research Centre (IDRC) of Canada signed a cooperation agreement by which IDRC financed the development and application of a method of integral analysis of electrical energy supply alternatives in rural areas.

The province of Misiones, located in the extreme north of Argentina, with a high percentage of rural population and with advanced experience in electric supply by conventional methods (medium voltage lines) and non-conventional methods (micro-hydros), constitutes an appropriate framework for application of the method. In particular, the Departments of Oberá and Cainguás in Misiones Province, with a high density rural population, were adopted as the study area. The study was undertaken by a team of experts from the IDEE and from the National University of Misiones (UNaM), whose participation was obtained by a cooperation agreement between the IDEE and the University Foundation of Oberá. The study was completed towards the end of 1986, and the final report contains the methodology and its application to the case of Misiones Province.

The conceptual framework for the study is the energy problem and the social process of its production, transformation, transport, distribution and consumption. The center of attention rests on the relationship between scant resources and unlimited needs and, fundamentally, on the social agents who have the power of decision over the resources and those who embody the needs.

The energy sector is taken as a subsystem showing strong interaction with the socio-economic system. Thus, the intention is to establish explanatory hypotheses for the energy phenomena within the wide scope of that system.

The planning process covers the whole energy subsystem, including the consumption sphere. It also considers demand, minimum level of requirement, the transformation process and the level of needs of different social groups attempting to investigate the influence of social, economic, cultural and environmental factors on the different requirements.

Overall, the dominant social accumulation process determines the structure of the added demand and thus the intermediate and final energy requirements. Hence, the energy area should be studied as a subsystem having multiple interactions and based on a social process where identification of the characteristics of the different agents or groups of agents is essential. Planning must be approached as a process for transforming this subsystem in accordance with the political objectives proposed for the socio-economic development project.

Objectives and Methodology

This study analyzes the problems of meeting the electrical energy needs of the rural household sector in regions of the Third World. In general terms, the use of energy by such rural populations is characterized by:

- The predominant use of the biomass as a primary energy source, consumed directly or with a slight degree of preparation (charcoal, firewood, agricultural or animal wastes);
- The limited use, for reasons of cost and supply difficulties, of oil derivatives (kerosene, gas oil, liquefied gas);
- The household uses of energy sources are those connected with basic needs (cooking, lighting, heating);
- Average energy consumption per user is very low in comparison with the rates recorded in urban spheres;
- Very low utilization yields result from the scant application of technology. The difference between the net and useful energy volumes is significant.

Within a low-income rural area development programme, how does progress in terms of energy sources and uses become evident? As regards sources, the programme should lead to the use of the best, most versatile forms of energy which in turn take advantage of the resources. Moreover, new uses should appear in the consumption structure as a result of the better satisfaction of needs.

Rural area household requirements should not be an obstacle to availability of electricity, since it is evident that a low density, dispersed demand includes adverse conditions for the purpose of introducing electricity into the countryside. Nevertheless, those are the most frequent conditions and the solutions proposed must be adapted to them. Thus, it is necessary to analyze whether the methods which are proposed to the rural dweller for access to electricity are in proper proportion to the scale and spatial distribution of householders' requirements and whether they take into account socio-economic situations.

The usual forms of electricity supply to rural areas are called 'conventional' because of their widespread use and are either centralized production and distribution by means of medium voltage lines or isolated generation by means of generating sets driven by oil derivatives. As regards the first, the World Bank (1976) casts doubt on the benefits of this type due to high costs from the high level of underutilization of the installed capacity evident during the first ten years and to the impossibility of establishing tariffs. A report by Fuitman (1983) warns of the negative economic and social results obtained with rural electrification projects. In connection with the second form, criticisms focus on the high fitting out cost, operation difficulties (cost and transport of fuel in zones characterized by deficient roads) and the absence of accessible credit lines. Hence, the so-called 'conventional' alternatives do not fit the needs or the socio-economic profiles of the rural areas.

This could explain the complex, often absurd, pretexts in the economic justification of rural electrification projects which over-emphasize the demand or the impacts on the region in order to influence investment decisions.

The results achieved through utilization of conventional supply methods can be summarized as follows:

- Low relative coverage of rural zones (large areas remaining without electrical service);
- Within the area served, a relatively low degree of utilization of the service (ratio between number of users and dwellings in the area);
- Prevalence of subsidies, both for investments and for operating and maintenance costs.

Policies intended for production activity need to be combined with others aimed at achieving adequate levels of quality of life in accordance with the development programme to be undertaken. It is most unlikely that rural dwellers will join a process of restructuring and development of the present production situation, the effects of which will be visible in the medium term, if during that time they have to endure a quality of life below subsistence level.

Non-conventional energy supply methods can become alternatives to conventional methods to provide a solution to the rural population's needs. Decision-making at political level is easier if assisted by an appraisal method which combines supply models which comply with the objectives of the policy-maker, the requirements of the populations and the energy sources and technologies available in the region.

The general objective of the study is to develop an analytical method which facilitates decision-making in projects of electrical supply to rural areas with a low level of development. The proposed method of analysis should respond to the following specific objectives:

- Consider electrical planning as an integral part of the development planning of a previously defined area;
- Take into consideration the scale of requirement and the socio-economic context in which the proposed supply scheme will operate;
- Analyze the rural household energy requirements through an analytical model which will enable the consumption levels by uses and sources to be determined;
- Incorporate all the feasible conventional and non-conventional supply alternatives that the natural resources and technology development of the region allow;
- Develop a solution with the sources and technologies available which optimize the resulting supply programme in accordance with the policy-maker's objective;
- Analyze and compare the solutions on both micro- and macro-economic scale, allowing the policy-maker to choose the minimum economic cost solution or alternative solutions which would maximize other effects sought by the policy objectives.

The treatment of appraisal of alternatives on the supply programme scale and the simultaneous need to generate a basis of confidence in the policy decisions require the development of methodologies which solve the problems of comparative analysis of energy solutions. Nevertheless, this must not be reflected in higher costs of the study. The methodology should bring together the maximum amount of available secondary information and active field techniques in the region. The proposal implies organization of the study into the following modules:

- Regional socio-economic and energy diagnosis;
- Appraisal of the energy requirements of the rural inhabitant;
- Appraisal of the potential of the energy sources available in the region;
- Correlation between requirements and sources—choice of technologies;
- Planning of electric energy supply: Appraisal of alternative supply models;
- Results and preliminary conclusions for the policy-maker.

Synthesis of the Case Study

Socio-economic and Energy Diagnosis of the Region

The province of Misiones is situated in the extreme north-east of the Argentine Republic between the Uruguay and Paraná rivers and on the frontiers of Brazil and Paraguay. It covers an area of 29,801 sq. km. and has 650,000 inhabitants, 50% of which are rural.

The traditional development model of this region rests on a specialized agricultural production scheme of yerba mate, tea and timber. Agricultural production evolves from a preponderance of small-holdings in the rural area, where products constitute income goods.

The supply of primary products is faced with an oligopolic demand from the processing industry. Marketing chains are dominated by extra-regional agents. Agro-industrial activity shows pronounced stagnation with the sole exception of the forestry industry which has enjoyed sustained growth in recent years.

In this context provincial development was characterized during the decade 1973–1984 by moderate growth of the GNP with a sustained decline in per capita income, which is about US$1200/inhabitant per year (about 40% below the national average). Composition of the GNP shows a reduction in the agrarian sector and some progress in the tertiary sector.

The population displays very heterogeneous ethnic, cultural and spatial distribution features; 50% of the population is rural, revealing a strong tendency towards urbanization. A rapid perusal of the housing sector shows that only 6% of the dwellings have electricity, drinking water and sewers. The hospital and school facilities are deficient, mainly in the rural area. Infantile mortality is high (7.5% per thousand). The illiteracy rate is double the national average. The primary school drop-out rate is 60%.

From the energy viewpoint, Misiones is characterized by being a net importer of commercial energies. In other words, a large part of its requirements are supplied with resources not available in the province. The available resources are water, timber and sun. The first is barely exploited, while the second is exploited with very low yields. Annual consumptions of commercial primary energy reach approximately the following Toe volumes: Biomass (firewood) 100,000; hydraulic 360, oil 350,000.

In the electrical sector, a provincial enterprise, EDEMSE (Energia de Misiones Sociedad del Estado), partially supplies industrial consumption and almost all residential, commercial and public consumption. Industrial self-generation is very high (88% of the installed power in EDEMSE). Important user cooperatives take part in the distribution and marketing of the electric energy supplied by EDEMSE in the provincial hinterland.

The south-central region of Misiones contains a large part of the problems related to the rural population's quality of life and to the stagnation of production activities. This region is also characterized by high population density. Oberá and Cainguás were of greatest interest for application and adjusting of the appraisal methodologies.

Appraisal of Energy Requirements

In defining the methodological outlines two main aspects have been highlighted in dealing with the appraisal of user energy requirements. The first is the need to analyze energy consumption starting from final uses, including all the sources which participate in it and from there to identify the possibility of incorporating a new energy form, in this case, electricity. The second aspect is to identify homogeneous modules or groups of users with similar requirements of electric energy, when it involves planning the supply of large areas with a high number of non-electrified dwellings.

In Oberá and Cainguás, the study area adopted was that which remained outside the electrified profile (the electrified profile being understood to mean the area potentially served by the rural medium-voltage lines), and consisted of 13,000 dwellings without electricity (National Population and Housing Census, 1980). The 6,000 dwellings without electricity are located within the electrified profile, while 7,000 are outside it. The large number of dwellings without electricity within the scope of the existing lines is indicative of the low utilization index of the service to be found in the rural areas of Misiones. The definition of the study area outside the electrified profile assumes that the idle capacity of the existing lines will be covered by demand from these users.

Identification of the population without electricity established three homogeneous modules known as A, B and C. These modules represent decreasing energy requirements and were characterized from housing indicators. For each module the energy requirements by sources and uses were determined by means of polling more than 250 rural producers. The questionnaires were given to users of electrical energy from the existing rural networks, users of electrical energy supplied by micro-hydros and potential users without electricity supply.

The questionnaires were designed to survey data on:

- Housing indicators which would define modules;
- Ethnic origin and cultural characterization;
- Family composition and production activity to define capacity for saving;
- Level of social participation to infer user willingness to cooperate in small, self-organized systems;
- Consumption by sources to determine net energy;
- Uses and characterization of household fittings to define yield and useful energy;
- Penetration of the electric energy in each use from the date of connection and daily habits of using appliances to determine power demand and daily load curve.

The questionnaires permitted the construction of matrices of uses and sources through which the specific net and useful energy consumption of each module was calculated and projected to the year 10 (the study horizon). From there the net energy requirements for the different sources are estimated by family and total. Finally, taking into consideration the electricity penetration assumptions and the habits of use of domestic installations, the power required for each module is determined.

Analysis of the matrices of uses and sources gives several conclusions. Useful energy consumption in the non-electrified rural household sector is supplied with firewood and biomass wastes in percentages varying between 76 and 92% of the total, according to the income categories considered. In the same way, for the electrified rural dwellings (17% of the total), the participation of firewood and biomass wastes oscillates between 59 and 71% of total consumption. The participation of electricity in the rural household consumption of net energy varies between about 7 and 11% for the different income levels considered. If these participations are calculated for useful energy, the values range between 16 and 27%. More than 90% of the electricity consumption is directed towards lighting, household appliances and food preservation. The use of lighting increases to the extent that the income of the users decreases (varying form 26 to 36%). The use of household appliances shows no noticeable variations in participation on the basis of income (from 29 to 32%). Food preservation decreases (form 33 to 26%) with income.

Projection of requirements for non-users was carried out on the hypothesis of substitution of sources based on the information from the polling of supplied users. In these hypotheses it is noteworthy that electricity is not used in cooking and is used only marginally in water heating, space heating, air conditioning and water pumping. Penetration of electricity provokes the substitution of kerosene for food preservation and liquefied gas and kerosene for lighting.

Projection to the horizon year of electricity energy demand for the whole study area gave a result of 12,500 MWh/year. Out of this total, 92% corresponds to consumption by medium and low income level population (modules B and C).

Table 1.1 Energy and Power Requirements for Homogeneous Modules

Module	Income Level	Energy Demand KWh/year		Power Demand (W) Horizon Year (1994)	
		1984	1994	Isolated users	Groups of users
A	High	1278	1673	1760	1060
B	Medium	764	1159	1320	764
C	Low	450	551	880	375

The main conclusions to be drawn from this section of the case study can be summarized. It is necessary to make a detailed study of users' energy needs to avoid making the optimistic energy consumption forecasts which have been used so often in the design and appraisal of investments in the centralized model and which afterwards have not been borne out by the facts. User categories show that there are wide differences in the energy needs of each of them, even inside the same region. In turn, the limited saving capacity of these users implies a slow process of integrating electric appliances into a rural dwelling. This is reflected in energy consumption averages for the periods in which the financial services of the investment programmes must be attended to, far below those which are customarily forecast.

The requirements analyzed at the correlation level of sources with final uses facilitate the proper dimensioning of electric energy penetration based on a rational, balanced use of the energy resources available in the region. From this viewpoint, dealing with requirements also allows incorporation of sectorial strategies of restructuring of the regional energy model and demands originating in the production strategies of the regional development plans.

It is advisable that in future, penetration of electric energy be analyzed on the basis of the design of electric household appliances suitable for the rural user. The adaptation of kerosene to electric refrigerators and the development of economic water heaters and fans made with local materials are some examples. These would allow more rapid electricity penetration with its subsequent improvement of the quality of life of the rural inhabitant and would be better solutions to the power demand.

Detailed analysis of the energy and power requirements has revealed the low load factor which characterizes the supply to the rural sector.

Appraisal of Energy Resources

Since sub-tropical forest covers a large part of the province and particularly the study area, firewood is the present energy biomass source. It is supplied from non-commercial species of the native forest whose yield is around 150 cubic m/hectare. The local firewood market is supplied mainly from reforestation clearings with species for cellulose purposes and from sawmill wastes. Being handled in perpetuity, the native forest has yields of 10 to 15 tonnes/hectare/year, and some rapid-growth exotic species have yields higher than 15 tonnes/hectare/year.

Where topographical characteristics are favourable, winds of regular intensity (3 to 5 m/sec.) and permanence (6 to 3.5 hours/day) are recorded; this is sufficient to produce energy at the level needed by rural users. Since the province is covered by a dense hydrographic network fed by abundant rainfall which varies from 1,650 to 2,100 mm a year for the study area, the hydro resource is the one which offers the greatest potential. However, its appraisal is complex due to the absence of hydrological records which would permit evaluating the Gross Theoretical Hydroelectric Potential and because the evaluation methodologies of the Theoretical Exploitable Hydraulic Potential refer to the exploitation of the basis by means of larger-scale utilization rather than micro-generation.

The difficulty in calculating the GTHP was overcome by correlating hydrometeorological and hydrometric parameters for known basins with similar characteristics to those of the study area. The second difficulty was solved by developing a suitable methodology for calculating the TEHP on micro-generation scale as a fraction of the GTHP adjusted by coefficients determined with field studies on representative pilot basins. The main results of the application of this method were:

- Specific yields of the basins were 17.8 liters/sec. per sq. km. for Oberá and 20 liters/sec. per sq. km. for Cainguás.
- Percentages of the GTHP utilizable on micro-generation scale were 5.5% in Cainguás and 4% in Oberá.
- Density of utilizable power on micro-generation scale reached maximum values of 7.65 KW/sq. km. in Cainguás and 4.35 KW/sq. km. in Oberá.

Finally, through analysis of cartographic and aerophotographic secondary information, 430 potential hydraulic micro-exploitations were located for the basins of the area, the continuous power in each of them being established.

Choice of Technologies

The methodology is based on the planning of supply alternatives which combine various methods of production of electricity. These alternatives are structured on two basic models—the centralized and decentralized. The centralized model is based on the present method of supplying electricity by rural networks connected with the medium and high voltage systems of regional or national scale. The decentralized model is based on the optimum combination of varying methods of supply both conventional (motor generators driven by oil derivatives) and non-conventional (based on new sources and alternative technologies).

The lower relative diffusion of the decentralized model makes it necessary to define some basic guidelines which characterize it. Firstly, it should be built up on the basis of the sources available in sufficient quality and quantity in the region. Secondly, the conversion of the energy of these sources to electricity should be undertaken by technologies that are simple in execution, operation and maintenance, with the greatest possible degree of local integration and with an acceptable degree of reliability. In other words, they must have completed their development stage up to the level of pilot plants on a scale similar to that which will be used in the model. Also, the decentralized model is a set of small systems self-organized by the users. This configuration implies a restriction to the module of the equipment which could be used in the model and consequently to the scale economies. Both the technologies for construction of equipment and the institutional design of the small systems of administration, operation and maintenance of the electric service must be adjusted to the cultural base of the receiver community.

In the case being studied the following supply methods were considered for constructing the decentralized supply model:

- *Micro-hydros*: constructed on sealing structures, easily constructed locally (earthfill, rockfill, etc.) equipped with Banki type turbines, synchronous generation and electronic regulation with transmission by 13.2/7.6 KV lines when the distance between sources and load centers so requires. The equipment module is adjusted to a range of power of 4–50 KW.
- *Thermal micro-power stations*: based on motor generators with diesel engines with oil derivatives, or else fitted with Otto engines and driven by lean gas produced from charcoal. The economic analysis determines the thermal supply method for assembling the model. The equipment will adjust its module to a power range of 4–50 KW.
- *Wind generators*: based on three-blade, low start-up torque, windmills with direct current generators and bench of batteries.

Each of the components into which the supply methods described are broken down was typified and standardized for the production scale considered. This is a prerequisite for planning the decentralized model, since on the technical plane it allows a rapid assembly of the alternative supply solutions and on the economic plane it facilitates evaluation by operating on a data bank of costs previously prepared for all the standardized series. Two basic cost matrices were constructed, the first referring to the investment costs and the second to the operating and maintenance costs. The investment costs matrix carries each of the typified components of each supply method and the total market price, disaggregated into a subset of items of regional incidence (local material, labour and overheads) and another subset of values of extra-regional incidence (national and imported material and capital costs). The operating and maintenance costs matrix carries all the supply solutions which have differentiated operating costs The supply solution shows two subsets of values, one with regional effects (local material, freight, labour and overheads) and the other with extra-regional effects (purchase of electric energy and fuel, national and imported material and capital costs). The currency used in the study is the Austral and the values correspond to the month of August 1985 (1 US$ = 0.80 A).

The investment costs data base was prepared starting from market prices when dealing with commercial components (piping, generators, conductors) or else with a detailed study of standard costs for the region for the components which have no wide commercial diffusion (Banki turbines, wind generators, lean gas-power stations, hydraulic sealing structures).

The basis of operating and maintenance costs for the centralized model was constructed starting out from real costs (without subsidies) of the electrical energy placed in the lines of the 13.2 KV system existing in the region. It is necessary to emphasize this aspect of the costs treatment since analysis of the different subsidy mechanisms (preferential prices to cooperatives, transfer of income among categories of users) in the case of Misiones detected differences of more than 300% between the cost and the tariff of the rural service.

For the decentralized model, the operating and maintenance costs were determined starting from the local experience acquired by the user associations which administer the micro-hydros and simulating dispatch in the case of the thermal micro-power stations (for which no experience exists in the region).

Planning and Appraisal of Alternatives

The micro-economic analysis was carried out on the assumption that all the solutions offer the user the same benefits. Therefore, the most suitable solution is that of minimum cost. Comparison of alternatives was made by evaluating prices from the point of view of the economy as a whole. In that sense, conversion factors were estimated which would enable the market prices to be taken as accounting prices, adjusting the cost components (especially foreign exchange, labour, fuels and inputs from the electric, metal and construction industries).

In view of the diversity of components of each installation and their different useful lives, it was considered that the most convenient evaluation criterion was the Equivalent Annual Cost.

A computerized system enables the data bank of market price costs to be converted to a data bank of accounting price costs by means of the conversion factors referred to above. Acting on the accounting price data bank, the system permits choice of the minimum economic cost solution from among the different supply alternatives by simply informing it of the type and quantity of technological components and the number of users of each of them. For calculating the Equivalent Annual Cost a discount rate of 8% a year was adopted in the case study.

The stage of formulation and appraisal of the supply programme for the area was developed in the case study in two phases: Planning and assembly of the alternative supply models; and economic and financial evaluation of the alternative models.

During the planning phase and by means of cartographic techniques based on census information and on aerial photography of the region, the spatial distribution of the energy and power demand was studied, grouping the potential users into load centers with a radius of 750 metres (scope of the low voltage lines). The result of the study of spatial distribution gave 553 load centers with a total of 5,794 users representing a hypothesis of 85% for the degree of electrification of the area. This study area was divided into regions (14 in Oberá and 13 in Cainguás), and each region was in turn divided into sub-areas. Each sub-area contains a number of users (minimum: 4, maximum:75) adjusted to the range of fitting-out modules indicated for the study.

Assembly of the decentralized supply model was based on comparison of supply alternatives at each sub-area level, including wind generators, micro-hydros and motor generators using oil derivatives or lean gases. By a prior selection study it was possible to establish that for the extension and quantity of users characterizing these sub-areas, the following applies:

- The wind generators have an equivalent annual cost higher than any alternative thermal solution and consequently they are not considered in the assembly of the decentralized model.
- For loan centers with less than 15 users, the motor generators with oil derivatives have the lowest Equivalent Annual Cost, while for load centers with 15 or more users the best solution is a gasifier.
- When the sub-areas have three or fewer load centers, the most suitable thermal solution is a motor generator.
- If the sub-areas have four or more load centers, it is most convenient to put in a single motor generator for the whole sub-area, linking up the load centers by means of medium voltage lines.

In this way, the decentralized model was reduced to comparison between thermal and hydraulic alternatives. Where the hydro resource was not enough or zero, the best thermal solution was adopted for equipping the sub-area. The resulting decentralized model showed a minimum cost configuration comprising 90 micro-hydros, 58 motor generators with lean gas and 38 motor generators with oil derivatives. Out of the total number of users (5,794), about 36% are being supplied from micro-hydros, 50% from lean gas-driven motor generators and 5% from oil derivatives.

Unit costs of the installed power in generation bars, taken as average costs of the resulting model and calculated at market prices were: micro-hydros 1271A/KW (US$1,589), motor generators driven by lean gas 382A/KW (US$477), motor generators driven by oil derivatives 470A/KW (US$587). The average power modules to which these costs correspond are 20 KW for the hydraulic stations, 45 KW for the lean gas-driven motor generators and 12 KW for the conventional motor generators.

Assembly of the alternative centralized model was carried out by the extension of the existing lines in 13.2 KV distribution networks which supply all the load centers of the area. The extension was planned within each region to allow comparison with the corresponding decentralized model on this geographic scale. The model was equipped with 727 km. of medium voltage lines and 553 MT/LT step-down transformers, which established an average density of eight users/km. of line and a transformer every 1,300 metres of line.

In the economic and financial evaluation of the alternative models, the centralized and decentralized models were compared for each of the 27 regions. In the micro-economic comparison at accounting prices the decentralized model had the lowest economic cost in all the regions, with values between 6 and 38% below the centralized model. The Equivalent Annual Cost of the whole area was about 18% lower for the decentralized model than for the centralized one.

Additional Information for Decision-making

While the micro-economic evaluation indicated the advisability of supplying the area by means of the decentralized model, the study was completed with the comparative calculation of the investments of each programme and the operating and maintenance costs updated for the series of 10 years at a discount rate of 8%.

The programmes were compared at accounting and marketing prices. The market prices in the centralized model were calculated according to the real costs and the subsidized tariff. From the results it is deduced that the advantage in favour of the decentralized model is enhanced when calculated at accounting prices (+ 12%) while at market prices it is almost the same (+ 3%). With values of the subsidized tariff in the centralized model, it comes first (- 42%).

From the financial viewpoint the decentralized model shows greater investment costs. In fact, the total cost at market prices is divided into 72% investment and 28% operating and maintenance costs, while the centralized supply divides its costs into about 40% investment and about 60% for operation and maintenance.

Sensitivity studies show that while the costs structure of the centralized system is maintained, its penetration possibility is limited to expansion of sales within the area served. In that case it would reduce its unitary operating and maintenance costs and achieve a penetration of 18% (approximately 1,000 users), preferably displacing the small thermal power stations and micro-hydros.

Macro-economic parameters provide a greater degree of information on the alternative programmes. The data bank has a disaggregation level which allows various parameters to be quantified. As regards investment costs, the motor generators which use oil derivatives have a higher participation in foreign exchange (13.3%), the local added value was maximized in the case of the micro-hydros (36.4%), the micro-hydros have the highest participation of local (14%) and unskilled (6.4%) labour and the greatest capital intensity is confirmed for the micro-hydros (91%). In general, the impact on the different indicators does not differ for the centralized and the decentralized model (the latter taken as the sum of micro-hydro, motor generator and gasifier installations).

As regards operating and maintenance costs, the lean gas-power stations have the most significant impact on the local added value (95.8%), and micro-hydros show the greatest impact as regards local labour (70.6%). Appreciable differences are noted between the impact of the centralized and decentralized models. In all cases the positive effects on local labour, local added value and unskilled labour are significantly higher for the decentralized model.

The decentralized system shows higher costs in foreign exchange but achieves a more positive impact on the local added value as well as on the labour, both skilled and unskilled. The centralized system has a significantly higher fuel cost.

Finally, a sensitivity analysis was done on a small system of 18 users representative of the results of the study. Supplies with lean gas-power stations, oil derivatives-power stations and micro-hydros were compared. The discount rate of 8% was modified as was the load factor of the small system (0.08 for this representative case).

Concerning sensitivity to the discount rate, the Equivalent Annual Cost of the small thermal power stations displayed little sensitivity to the discount rate while the micro-hydros showed important variations. For rates below 15% the use of the hydraulic source predominates. If this source were not available, the most convenient solution of thermal origin would be the lean gas-power stations with rates the same as or less than 8% and the diesel with higher rates. For sensitivity of the load factor, the decline of the energy price with the increase of the load factor is much more rapid for the micro-hydro than for the small thermal power station. For the discount rate of the study, the hydraulic solution has first place when the load factor is increased. For the thermal solutions the gasifier is the most suitable (at market prices) when the load factor is higher than 0.2.

The sensitivity analysis of the cost of energy with increased load factor shows that the decentralized model would allow the incorporation of production uses on a small scale with lower marginal energy costs than the centralized model. This situation indicates that an alternative model such as has been put forward can be optimized by integrating community production activities on the scale of each small supply system. This would not modify the fitting-out level and would improve the load factor.

Final Comments

Finally, it should be emphasized that to achieve greater political willingness to bring mass diffusion of the use of new sources and alternative technologies suggests a new starting point on a road which is little known. The juridical, institutional, social, environmental, economic and technological dimensions must be thought out and prepared so that the new model can be converted from simulation to reality. Several questions have to be carefully appraised:

- Are the present electrical service utilities the proper institutional sphere for developing these new models? If so, how should they be prepared? If not, what is the appropriate institutional sphere?
- What juridical framework should be set up for the exploitation of natural resources on a small scale, and what would be the framework for the tasks of the users organized for self-supply? Which authority will exercise official control of the service?
- How much can be expected of the users in connection with energy self-operation? What technical and management formation actions should be undertaken? How are the natural leaders chosen and what are the dynamics of the social groups?
- How can the financing gaps be solved between user payment capacity and the costs of the model? Can the energy sector financing funds be used? What juridical or regulation modifications would have to be introduced for this purpose?
- Is the regional technical structure satisfactory for a fitting-out programme resulting from the new models? What actions should be structured for developing the suppliers? What actions of technology transfer and adaptation must materialize for starting up the programme?

The replies to this set of questions will enable an overall proposal to be constituted which will allow the policy-maker to begin a supply programme based on the new model with the consequent diffusion of the alternative technological solutions.

2

Socio-Economic and Energy Diagnosis

The objective of the socio-economic and energy diagnosis is to single out the general elements which lead to the socio-economic behaviour of the area under study, stressing the structural type aspects, attempting to detect the real aspects which contribute to deterioration of the area and obstruct its development and to identify the energy supply and consumption characteristics, as well as availability of regional energy resources.

Availability of Resources and Production Potential

Four natural homogeneous units can be distinguished in the province of Misiones in accordance with their structural features, geomorphological, climatic, edaphic and natural vegetation attributes. These units are Rio Iguazu, Sierra de Misiones, Rio Alto Paraná and Meseta Misionera.

These natural spheres outline a system of production and settlement potentials of various kinds. They also establish suitability of each of the homogeneous regions for human settlement, irrigated and non-irrigated agriculture, cattle raising, lumber, mining, commercial fishing and industrial and tourist activities. Table 2.1 summarizes the results of these indicators in accordance with the regionalization.

It can be concluded from the table that the provincial store of natural resources is not as abundant as might be hoped, attention being drawn to certain spaces where there is low stability of the natural medium. It must also be noted that provincial production includes a range of items (tea, yerba mate, timber and tung) adjusted to the production potentials offered by the natural medium.

Table 2.1 Natural Homogeneous Units

	Region			
Suitable for	Rio Iguazu	Sierra de Misiones	Meseta Misionera	Rio Alto Parana
Human settlement	Medium high	Medium high	Medium high	Medium high
Non-irrigated agriculture	Medium low	Medium low	Medium	Medium
Irrigated agriculture	Medium	Medium low	Medium	Medium high
Cattle raising	Medium	Medium	Medium	Medium
Lumber	High	Medium high	Medium	Medium high
Mining	Zero	Zero	Zero	Zero
Commercial fishing	Zero	Zero	Zero	Low
Industrial activity	Medium	Medium low	Medium	Medium high
Tourist activity	High	Low	Zero	Low

Limitations

Rio Iguazu	Relatively high frequency of torrential rains, liability to water erosion.
Sierra de Misiones	Relatively high frequency of torrential rains. Very high liability to water erosion. Desegregation of vegetation due to selective felling and slashing practices. Low stability of the natural medium.
Meseta Misionera	High frequency of torrential rains (especially in the south). High liability to water erosion. Low fertility soils, likely to drop rapidly. Degradation of the natural vegetation. Stability of natural medium, partially low.
Rio Alto Parana	Same characteristics as Meseta though without low stability of the natural medium.

General Provincial Development

The dynamics of the socio-economic system of Misiones is conditioned directly or indirectly by the agrarian sector. Dependence on agrarian-based activities leads to relatively unfavourable development conditions compared with regions having more balanced economic profiles as regards the participation of the different economic sectors.

The participation of primary activities in the generation of the Provincial Gross Product (percentagewise) is twice what it is at national level. Local industrial activity is backward compared to national level. Thus, analysis of the economically active population shows that while the country retains 13% of the population occupied in the agrarian sector, the rate in the province reaches 39%.

The industrial sector is characterized by being essentially the sphere of transformation of primary products. The province is articulated into the national system as a complement of the activities being carried out in the central region of the country, where the general conditions of national accumulation are dictated. Thus, Misiones shows important specialization in industrial crops whose relative participation at national level is very evident.

Another element contributing to low development is inferior productivity compared to the national economy. In fact, in all activities, except construction and transportation, the average provincial productivity varies between 20 and 80% of the same activities obtained at national level. There is a very noticeable low capacity for adding wealth, the per capita incomes being about 30% below the national average.

Production characteristics are defined by the predominance of a considerable number of small producers with very low productivity who lack capacity for generating accumulative processes which would allow them to amplify the scale of activity. These production units are marginalized from industrial assignment of the resources they use, among which the most important is the family's own work force. However, the segment of small producers does not explain the whole of the supply since large-scale industrial units also operate with totally different criteria of resource assignment. There is a strongly atomized supply which must confront a demand having clearly oligopolic features and which imposes the negotiating conditions. Furthermore, the majority of the agents who control the final phases of the chains originate outside the region; regional capitalization of accumulation is thus minimized.

The growth rate of the Geographical Gross Product has been restrained over the last ten years. The areas of lowest growth were agriculture, industry and trade. In this sense and with the exception of the increases found in the paper industry, there is stagnation of the industrial sector. Almost all the dynamic activities of the province are oriented towards the rest of the country or the rest of the world. Bearing in mind that the local forces exert almost no pressure whatever on establishing the prices of their products, this element must at once be pointed out as a new limiting factor of provincial development.

Demographic and Social Infrastructure

The province of Misiones has about 650,000 inhabitants with a density of 21 inhabitants/sq. km. and a growth rate of 2.7%. Misiones receives and expels important contingents of migrants who determine its demographic, economic, social, political and cultural configuration.

The demographic structure is characterized by a high rate of population growth, a moderate general mortality rate but an extremely high rate of infantile mortality, a very young population pyramid, a negative migratory balance and unequal spatial distribution of the population. Although it is still the most rural province of the country, the degree of urbanization is on the increase, having become more notable since the 1960s. The explanation for this is the maximization of economies, more satisfactory conditions of life and better supply of public and service installations in the urban sub-sectors.

The infrastructure of housing, health and education can be summarized as follows:

- About 80% of the dwellings are houses, 13% precarious constructions and 3% shacks. The degree of overcrowding in urban areas has grown in recent years; compared with a growth in urban population of 79%, the number of dwellings increased by about 62%.
- According to the 1980 census, only 6.3% of the urban dwellings had electricity, water and sewers.
- Infantile mortality rates reach between 66 and 74 per thousand for different regions of the province. The province has 3.9 hospital beds and 13 doctors for every thousand inhabitants.
- Out of every thousand children entering the first grade of primary education, only 40 reach seventh grade.

It would seem from this brief socio-economic diagnosis that a moderate growth of economic activity can be expected, maintaining the per capita income and a very slow improvement of quality of life at provincial level.

Provincial Energy Situation

Misiones' energy requirements are met by resources that it does not have. It is a net importer of oil derivatives coming from oilfields and refiners located at distances varying between 1,000 and 3,000 km. As a counterpart, the province's primary energy resources are water, firewood, sun and wind. Utilization of the hydraulic potential has been very low and the disorganized handling of firewood has been one of the causes of increased degradation of this resource.

Estimated hydro reserves vary from 20 to 2,500 MW. In the rivers, the following hydraulic schemes have been identified: Yaciretá (2,300 MW), Corpus (4,600 MW), Itati Itacorá (1,100 MW), Roncador (3,000 MW) and Garabi (1,800 MW). The hydro resources exploited consist of two power stations of 0.7 MW each, while presently in construction are the dams of Urugua-i (110 MW) and Yaciretá (2,300 MW).

Firewood is used in the industrial and household sectors. The largest consumptions occur in steam production in the paper cellulose industry and to a lesser extent in citrus and olive oil industries and yerba mate and tea dryers. In the household sector it is used for cooking and water heating. Forest statistics show that the consumption of firewood as energy reaches 290,000 cubic metres a year.

The supply of electricity is the responsibility of an official entity and 13 private cooperatives. The official entity is a mixed company which covers generation, transmission and distribution. The cooperatives only distribute, buying in block from the official entity, EDEMSE, which is responsible for more than 90% of the generation, transmission and distribution of electricity.

The provincial electric system is not part of the National Interconnected System and comes under the jurisdiction of the provincial authorities. The interconnected provincial system is basically made up of a 132 KV line (270 km.) extending from Posadas towards the north-east along the banks of the Paraná River, with a branch towards the city of Oberá, completed with 33 and 13.2 KW lines. The future entry of Urugua-i and Yaciretá will substantially modify the configuration of the system.

A high percentage of self-production of energy exists, essentially in the industrial sector, with an installed power of 69 MW. This is due in part to the low reliability of the public utility and partly to the use of steam obtained from other manufacturing processes. The average annual consumption per user is 2,500 KWh, Misiones being one of the least electrified provinces of the country, with an electrification degree of 44% (residential users/polled dwellings).

The rural electrification lines (13.2 KV) have a length of more than 2,500 km. The low density of users makes supply to rural areas extremely expensive and very difficult to put into effect through conventional means. A large part of the rural sector has no electricity due to dispersed spatial distribution and a low load density which means that supply with centralized systems is not feasible or very difficult to implement. Hence, there is a need to appraise other supply alternatives which at least would allow present restrictions to be reduced. In the socio-economic situation described and in the face of the energy situation of the rural areas, it seems correct to assume that the supply of electricity to these areas could improve quality of life and open the way to structural changes which would modify the present socio-economic relationships.

3

Present and Future Electric Energy Requirements

The object of this chapter is to estimate the electricity requirements of non-electrified rural dwellings. This estimate requires analysis of energy consumption starting from the end uses, including all the sources and thereafter to identify the possibility of incorporating a new form of energy—electricity. The estimate is made for each consumption unit located geographically with reference to the forecast consumption in the horizon year of the study (1994), defining homogeneous modules according to a stratification by income level.

In the first part the present energy requirements of the electrified and non-electrified population are analyzed from questionnaires which allow the construction of a sources and uses matrix by which the specific consumption of net and useful energy of each homogeneous module is calculated. In the second part, hypotheses establish the specific consumptions in useful energy projected to the horizon year. From there, the requirements of net energy for the different sources are deduced by family and total area. Finally, taking into consideration the assumptions of penetration of electricity and habit of use, the power required for each module is established.

The rural population of Oberá and Cainguás was divided into three universes: Dwellings electrified by the conventional system (U.1), dwellings electrified by the non-conventional systems (U.2) and non-electrified dwellings (U.3). The household units were taken as recording and analysis units for the survey of data through questionnaires. The basic nature of the uses of electricity in the rural sphere meant that the type of dwelling was regarded as a definitive element of the homogeneous module, assuming that a better quality dwelling would be associated with a higher income level and a greater energy demand. Each type takes into account the material used for the construction, sanitary services, drinking water, space conditioning and energy used.

Except for the users of micro-hydros (U.2) who were all polled, the remaining universes gave rise to different sample designs on the bases of the secondary information available in each case.

The conventional system of electrified dwellings (U.1) had the advantage of an adequate sampling framework consisting of lists of users of the companies providing the electric service: the electrical cooperatives of Oberá and Cainguás and the provincial utility, EDEMSE. The individual cards of users were used as the data source, giving the following: name, geographical location, type of user and monthly consumption. The consumption records varied between three months and four years. The design of samples stratified by conglomerates thus led to a self-weighted sample which was reasonably close to a random sample. The questionnaires recorded 10% of the electrified rural dwellings, a total of 117 questionnaires being answered.

The conditions of non-electrified dwellings (U.3) were much less favourable for making a proper sampling. The main obstacle was inadequate initial study of the distribution of non-electrified dwellings in both Departments. It was therefore impossible in this case to conform to a probablistic design. The decision taken was to guarantee a certain geographic dispersion of the questionnaires, one hundred of which went to this population of 13,042 dwellings. Eleven census zones were chosen, distributed over areas with different characteristics, and in each of them between 8 and 10 questionnaires were distributed. The choice of the dwellings within each census zone was random.

In view of the small number (25) of dwellings electrified with micro-hydros (U.2), it was decided to poll them all.

In accordance with the sampling design, 242 questionnaires were made. The poll was made up of the following data blocks: Composition of the domestic unit, agrarian exploitation data, characteristics of the dwelling, energy sources (types of fuel, origin, price, quantity, supply problems), uses of energy (lighting, appliances, cooking, sanitary hot water, space heating, food preservation, obtaining drinking water), frequent and/or future uses of electricity and economic situation of the household unit.

The results of the questionnaires showed that the conventional users have a smaller size family. Even the poorest sectors send their children to school due to the meals served in all rural schools.

The main activity of the head of the household has been grouped into three categories: Agriculturist workers who might have other complementary jobs, rural labourers who work permanently or temporarily and others (teachers, storekeepers, independent workers). Agricultural workers make up about 76% of the conventional users and 55% of the non-electrified users. Rural labourers constitute a quarter of the non-electrified and a scant 8% of the conventional users. Rural labourers appear in none of the micro-hydro projects surveyed. This points to the little opportunity these workers have of joining a consortium due to their reduced economic means and to the difficulty of devoting unpaid working time to the construction of the facility.

The number of hectares in cultivation is a significant indicator; 55% of the non-electrified users have less than 9 hectares being cultivated, while 10% of the electrified users have less than 9 hectares. The low economic level of the non-electrified units is consistent with the educational level of the head of the family, since only 5% of them had completed primary school. As regards the non-conventional electrified users, 38% had reached that educational level.

The degree of formal education, apart from being an indicator of the socio-economic level, is relevant as regards willingness to accept innovations. Once again, the contrast between electrified and non-electrified users, particularly at the lowest level, corresponds to a situation of functional illiteracy.

The information on the ethnic extraction of the family unit was constructed by combining the data on the country of birth of the husband and wife and of their parents and grandparents with the information on the languages currently spoken in the house. The conditions of the population of Misiones make this information significant, it being a recognized fact that the 'creoles' and 'foreigners' inserted themselves differently into the economic structure (the former as labourers, the latter as colonists) and that these stereotypes function ideologically to explain the different economic situation of both. A significantly lower number of creoles can be verified among the conventional users on comparing them with the non-electrified (42% and 74% respectively). Again, the non-conventional electrified users appear in an intermediate position with respect to the other groups.

It was considered interesting to obtain a measure of the degree of social participation for the purpose of orienting proposals on the ways of carrying out construction. The most important social institutions in Misiones are the school and parent-teacher union, the church and the agricultural cooperative. The highest level of social participation was found among the non-conventional electrified users.

The questionnaires allowed some conclusions to be drawn from the socio-economic point of view. The samples chosen make up a reasonably good expression of the populations to which they correspond, although a slight over-representation can be seen of the higher income group among the electrified users. The data consistently express a higher socio-economic level of the household units which have electricity compared to the non-electrified units. The project, according to this general description, is clearly directed at establishing the electricity needs of the lower socio-economic level rural sectors of the region.

Estimate of Present Energy Consumption

With the information collected through the questionnaires, it is possible to construct the energy sources and uses matrix corresponding to each of the sub-universes. The values in each of the matrices correspond to the consumption of annual net energy per family for a given source and use. They are expressed in kilograms of oil equivalent (Koe). The value of each source/use position of the matrix of each sub-universe is the average of the values obtained by polling. Starting from the net energy values and considering the yield coefficients by use and source, the specific consumptions (by family) in useful energy are calculated. The energy sources, use categories and homogeneous modules defined appear in Table 3.1.

Table 3.1 Energy Sources and Uses

Sources	No.	Description	Code
Primary	4	Firewood	FW
	7	Trad. biomass wastes	TW
Secondary	23	Liquefied gas bottles	LGB
	30	Kerosene	Ke
	34	Gas oil	GO
	39	Charcoal	Ch
	45	Electric energy	EE

Uses	Code	Category	Code
Cooking	Cok	Heat	Ht
Water heating	Wht	Heat	Ht
Space heating	Sht	Heat	Ht
Food preservation	Fpr	Cold	Cd
Air conditioning	Air	Cold	Cd
Household appliances	Hap	Power	Pr
Pumping	Pum	Power	Pr
Lighting	Lig	Lighting	Lg

Homogeneous Modules		
EL	IN	Description
1	1	High income level electrified
1	2	Medium income level electrified
1	3	Low income level electrified
2	1	High income level non-electrified
2	2	Medium income level non-electrified
2	3	Low income level non-electrified

Regarding electrified dwellings, taking into consideration the number of inhabitants per family (average size of the family for each type of dwelling), it is possible to calculate specific consumption per inhabitant in useful energy (see Table 3.2). The values obtained bear out the advisability of having differentiated income levels on the bases of type of dwelling. In fact, each category A inhabitant consumes 40% more useful energy than the corresponding one in category C.

Table 3.2 Specific Consumption in Useful Energy (Koe)

Type	Per family	Family	Per inhabitant
A	270.67	4.098	66.05
B	257.19	4.819	53.47
C	219.42	4.372	46.37

Regional Electric Energy Use

From the information collected through the polling of users of the Conventional Electricity Supply System, a series of highly useful elements of judgement for the study can be extracted, concerning the way the population has incorporated this source into their energy requirements.

More than half of the users inhabit type B and C dwellings, and about 72% of the connections were made after 1980. The insufficient connection period of the users limits the scope of comparisons made later on. Billings to rural users made available by the distribution companies of the region allowed comparison of the average consumptions resulting from consideration of the whole universe and the sample surveyed, as indicated in Table 3.3

Table 3.3 Annual Average Consumptions by U.1

KWh	Sample		Universe
	A Dwellings	B Dwellings	
0–200	1.4	2.4	4.5
201–400	2.9	17.1	9.7
401–600	8.7	31.7	17.0
601–800	20.3	61.0	30.3
801–1000	34.8	70.7	48.8
1001–1200	52.2	92.7	61.5
1201–1400	63.8	97.6	70.5
1401–1600	75.4	100.0	78.0
1601–1800	85.5		82.8
1801–2000	88.4		86.6
2001–2200	91.3		91.2
2201–2400	94.2		93.3
2401–2600	100.0		100.0
Total	69.0	41.0	908.0
X	1,278	764	1,076

Source: Conventional users poll and consumption data of the electricity suppliers.

The values point to a clear difference between consumptions of type B dwellings (X = 764) and type A (X = 1,278). Type C dwellings were not considered as they were so few. This result proves the close relationship between characteristics of the dwelling and consumption of electricity. It should be noted that the value corresponding to the Universe (1,076 KWh/year) is very similar to the weighted average calculated starting from the values obtained in the sample (1,086 KWh/year). This similarity confirms the representivity of the sample.

Table 3.4 shows the percentage of penetration of electricity in the different uses, according to the type of dwelling.

Table 3.4 Penetration of Electric Energy (percentages)

Uses of Electricity	Dwelling A	Dwelling B	Index B Value (A = 1)
Water heating	20.0	8.1	0.40
Space heating	13.3	0.0	0.00
Food preservation	93.3	70.3	0.75
Air conditioning	48.3	21.6	0.45
Household appliances			
Television	93.3	91.9	0.98
Electric iron	98.3	73.0	0.78
Washing machine	60.0	43.2	0.72
Pumping	66.7	10.8	0.16
Lighting	100.0	100.0	1.00

Source: Conventional users poll.

With the exception of lighting and television, the other uses reveal a greater penetration of electricity in the type A dwellings. Worthy of note is the penetration achieved among type B dwellings by expensive installations such as television and refrigerators, in contrast to lagging in the case of the iron, which has a relatively low cost. The low incidence in both groups of space and water heating is explained by the climatic conditions of subtropical zones.

Another angle which enhances analysis about penetration of electricity is obtained by considering the combinations of uses to detect whether these respond to some pattern. This analysis uses the scalegram developed by L. Guttman which permits determination of the degree to which a set of items or replies can be graded, in this case the main uses of electricity. Table 3.5 shows the application for users with type B dwellings, since it is considered the most significant population. The bottom line indicates the percentages of users who have incorporated each of the uses considered. The table also gives information about the most frequent combinations of uses. Each row of the table represents a given pattern of uses, in which X means the presence of the use and - its absence. To each pattern a score is awarded equal to the sum of the positive replies. The uses have been arranged from lowest to greatest degree of diffusion, excluding lighting which reaches 100%.

Table 3.5 Scalegram of the Main Uses of Electricity in U.1.B Dwellings

Air conditioning	Washing machine	Electric iron	Refrigerator	Television	Points	No. of cases
X	X	X	X	X	5	3
-	X	X	X	X	4	6
X	-	X	X	X	4	3
X	X	-	X	X	4	1
-	-	X	X	X	3	11
-	X	-	X	X	3	1
-	X	X	-	X	3	4
X	-	-	X	X	3	1
-	-	-	X	X	2	3
-	-	X	-	X	2	3
X	-	-	X	-	2	1
-	-	-	-	X	1	2
-	-	-	X	-	1	2
9 (22%)	15 (37%)	31 (76%)	33 (80%)	37 (90%)	124	41 (100)

If there were perfect scalability this would mean that all the users of refrigerators would also have televisions, all users of irons would also have refrigerators and televisions and so on. The line should have all the Xs at its right and all the - at its left, so that any X in the lower left-hand side of the diagram is considered an error, the same as any - in the upper right-hand part. The coefficient of reproducibility is then calculated subtracting from the unit the proportion of errors observed, the proportion resulting from the coefficient of the number of errors over the number of possible replies.

This case involves 41 users polled who reply to five items (or main uses), resulting in 205 replies out of which 32 errors were recorded. Thus:

$$R.C. = 1 - \frac{32}{205} = .84$$

The value .84 is slightly below the minimum acceptance for Guttman, which would be .90 (perfectly scalable items would give a value equal to 1).

Summarizing the analysis of U.1 penetration of electricity, it can be concluded that most of the electrified rural population was connected to the network in very recent years, a phenomenon seen most clearly in the case of users with type B and C dwellings. The annual average consumption of electricity rises to 1,076 KWh; however, it falls considerably for the inhabitants of the B dwellings (764 KWh). Users with B dwellings (and presumably the Cs also) have been slower in becoming connected to the network, and once connected, penetration of electricity in different uses is slower than in the case of the As. In addition to lighting, the refrigerator, television and electric iron display the most penetration, both for the As and Bs, with percentages higher than 90% in the As. Other uses which arouse great interest and which have penetrated significantly in the As (but not in the Bs) are water pumping and washing machines.

The Non-electrified Population

Estimate of Payment Capacity

According to the data, 80% of the non-users earn their income from agriculture. In view of this situation, the Gross Income which each crop provides per hectare was calculated at present values. Subsequently, from the data in block 2 of the poll, the incomes corresponding to each of the dwellings polled was established.

In the payment capacity concept, two fundamental components can be recognized. On the one hand, it involves whether a given household unit has at its disposal a certain amount of cash income over and above the minimal necessary expenditures for reproduction susceptible to application to some purpose. In effect, some surplus has to exist which could be expressed in a certain number of Australes per month. On the other hand, the sole presence of a surplus does not reveal anything about the willingness of the members of the household unit to assign it to one purpose or another. This depends on a subjective evaluation (even when socially and culturally determined) to apply that surplus to one of the possible alternative purposes.

The concept of 'surplus' is certainly quite problematic. The problem lies in how to quantify the monthly minimum necessary expenditure, since this is a variable quantum in space and in time. The solution adopted here consisted of surveying the expenditures regularly incurred by the household unit in food, health, energy, schooling and maintenance of relatives not living in the household unit.

Once the expenditure was quantified, it was deducted from the monthly income in Australes to obtain a monthly surplus. A negative surplus which does not exceed 20 Australes per month means a zero payment potential, a situation which applies to 28% of the non-electrified population. The remaining categories correspond respectively to potentials of 'moderate' (21–50) and 'certain' (more than 50). If the distribution is considered by type of dwelling, there is a zero potential of 38% in the Cs, compared to about 22% among the As and Bs (considered jointly in view of the scarcity of As).

Consideration must be given to the subjective willingness to assign cash income to electrification. Non-users were asked whether the family would contribute money in order to have electricity. In type A and B dwellings 45% of the replies were positive; in the Cs only about 36% were positive. To the extent that the surplus increases, willingness to pay also increases, going from about 38% of positive replies for the surpluses not exceeding 20 A to about 43%. It is obvious that the ten household units willing to pay cannot be considered as having payment capacity but rather wishful thinking. Out of these 99 non-users, about 31% have payment capacity including the 'certain' and 'moderate' categories.

On the basis of these data it may therefore be concluded that about 69% of the non-electrified population lacks the means, willingness or both to become electrified by the conventional way.

Attitudes Regarding Electricity and its Potential Uses

In examining the attitudes towards electrification, the third question in the poll was: 'What would be most necessary to improve your living conditions in this place?' The replies were varied (tractor, land, loans, better prices) but 41% of the interviewed mentioned electricity as the most necessary. This indicates that electricity constitutes a perceived need for an important part of the population.

In an undirected stimulus question interviewees were asked what they would use electricity for. The replies were vague and also liable to fall into various systems of alternative categories. Recording all the uses, the following percentages were obtained: lighting (63), refrigerator (33), water pumping (13), television (12), washing machine (10), iron (9), tools (9), radio (3), fan (2). The sum exceeds 100 because several of the persons mentioned more than one use. There were also 9% who could not even visualize the proposed hypothesis.

One of the assumptions for the possibility of electrification by means of micro-hydros is the utilization of family labour in the construction of the schemes in such a way as to lower their costs. When asked about contributing labour in order to have electricity, about 46% replied positively.

It is also important to take into account the concrete conditions in which the work would evolve. In collective projects it is necessary to coordinate activities carried out by neighbours, which frequently gives rise to conflicts. Only one-third of those polled declared themselves willing to work together with all of their neighbours. Among those having a higher score in the Index of Social Participation, a better predisposition to working with everybody is observed (41%). An important proportion (28%) was not willing to work collectively. Readiness to work with neighbours is distributed according to type of dwelling. Excluding the A dwelling (due to the small number of them), it is observed that those who live in B dwellings are better disposed to community work than those of C dwellings. This is important because it means that the sectors in the worst economic conditions—for which therefore family work would represent the only contribution possible—are precisely those who would have the most difficulty becoming organized as a community.

In summary, the income levels of the non-electrified population are for the most part very low; for about 28% of the cases there is no surplus which could be assigned to rural electrification. If this fact is combined with explicit willingness to make the necessary investment for having access to the service, the market for the conventional electrification plans is slightly higher than 30% of the non-electrified population. Nevertheless, electricity appears as an important need to be met for a considerable sector of the population (about 40%). The most important use hoped for is lighting, but the refrigerator also creates logical expectations and could penetrate rapidly in the sectors with a higher economic level. There could also be rapid penetration for television. The remaining uses would penetrate much more slowly, either due to the magnitude of the investment in fitting out (pumping, washing machine) or due to the little interest they arouse (iron, fan). As regards the possibility of contributing labour, about 45% of the replies were positive. However, for different reasons (class conflicts, intense individualism) there is no pronounced predisposition towards collective work, especially in the least fortunate sectors.

Information from Micro-Hydro Users (U.2)

Even though the number of users of electricity provided by non-conventional systems is very small (25 dwellings), it is interesting to analyze the data related to the uses incorporated and the opinions of the users of this form of supply. Of the 25 users, four belong to individual projects and the remainder to three collective projects: Pereyra (11), Persiguero (4) and Villa Bonita (6). The last one operates in parallel with the public network. They were constructed between 1978 and 1985 and are all in the experimental stage. The differences in scale, technologies and seniority of the different projects seriously limit the possibility of generalizing the replies and information recollected.

Table 3.6 Uses of Electric Energy

Use	From micro-hydro		From other	Without	n
	no.	%	source		
Television	17	68	2 battery	6	25
Refrigerator	5	20	11 kerosene	9	25
Washing machine	6	24	4 gasoline	15	25
Fan	5	20		20	25
Water pumping	–	0	10 gasoline	15	25
Iron	16	64	1 LPG	8*	25

* Charcoal-fired iron used

Penetration of the iron and television (more than 60%) is noteworthy as is the slight penetration of the refrigerator, washing machine and water pump which continue to function with other energy sources. This latter situation may be ascribed to three reasons: the short time since the connection, power limitations in the generation systems and the absence of installations adequate for the limitations.

Most of the users are from projects started up only very recently, such as those of Persiguero and Pereyra. Also, data collection of this group took place towards the end of February 1986, at the end of four months of the most serious drought in living memory. The scarcity of water created a crisis for all the hydroelectric generation systems, no matter their size. In Misiones, the drought also meant lack of water in urban centers as well as total or partial loss of harvests and numerous forest fires.

However, 90% of the persons interviewed considered that the installation of the micro-hydros was very convenient. A lesser degree of satisfaction was observed when asked if the electricity generated by the micro-hydro was sufficient for family needs, since 68% replied affirmatively. In accordance with these and other questions, the degree of satisfaction could be determined, the result being that for all the projects, 20% would be very satisfied, 44% moderately satisfied and 36% dissatisfied.

Open questions in the questionnaire elicited responses that lighting was one of the main advantages and that the micro-hydro requires practically no work for its operation.

The micro-hydros programme worked out with additional benefits in mind. One hypothesis is that the basin created by the construction of the dam could give rise to recreational and tourist uses. It was therefore interesting to inquire about this point. Eighteen of the persons interviewed mention its use for 'bathing' and swimming. In six cases its hypothetical use for fish breeding is mentioned and there are three mentions of using it for washing clothes. From this point of view, appraisal appears quite favourable.

Asking whether neighbours would be interested in installing a micro-hydro is another manner of measuring the success of the under-takings which gives a rough idea of the possibilities of diffusion. The replies varied in specificity and concreteness, but it is noteworthy that about 80% of the persons know neighbours who would be interested in this technology, and there were only about 20% negative answers. Over and above the concrete existence of other potential adopters of the innovation, the replies can also be interpreted as expression of a certain pride as innovators.

The micro-hydro is appraised positively as regards the possibility of utilizing electric light, a use which the household units do in fact value. However, the technical limitations may not meet the needs of certain user categories, at least for operation in conditions equal to the network. The difficulties for collaborating in execution of the work are greatest in the case of the least-favoured sectors, thus revealing a contradiction to be taken very much into account in the manner adopted for carrying out new schemes. Finally, it would appear suitable to incorporate the analysis of problems related to fitting out when posing decentralized systems of electricity supply, considering the difficulties arising from having only a limited amount of power.

Projection of Specific Consumption

Projection of energy requirements is carried out on the basis of a series of hypotheses deriving from the foregoing analyses. For the socio-economic parameters, it has been assumed that the quantity of population and the levels and distribution of income remain constant during the period analyzed. This implies that there has been no variation in the quantity or the ratio of dwellings A, B and C. For technical parameters, no variation has been considered of the yield coefficients of the equipment during the period of analysis.

The hypotheses of participation of electricity in the useful consumption by use, for the years n + 5 and n + 10 (horizon), are shown in Table 3.7.

Table 3.7 Participation of Electricity in Useful Consumption (in percentage)

	Income Level					
Uses	High (A)		Medium (B)		Low (C)	
	n + 5	n + 10	n + 5	n + 10	n + 5	n + 10
Water heating	15	20	7	10	0	5
Space heating	8	21	0	0	0	0
Food preservation	87	95	65	70	40	60
Household appliances	96	98	95	98	90	95
Water pumping	50	90	50	90	100	100
Lighting	100	100	100	100	100	100

Even though the income level and distribution have remained constant, it has been assumed that the presence of electricity will provoke an increase in the specific consumptions, except in cooking and space heating, which do not use electricity. To establish the values of specific consumption in useful energy in the division years, those corresponding to the electrified population (U.1) were used as references. In Table 3.8 details are given of the values of specific consumption by use in Koe/family, for the different homogeneous modules.

Table 3.8 Specific Consumption by Use (Koe/family)

	Income Level					
Uses	High (A)		Medium (B)		Low (C)	
	n + 5	n + 10	n + 5	n + 10	n + 5	n + 10
Water heating	4.36	10.23	2.12	4.34	1.29	3.21
Space heating	2.00	2.50	-	-	-	-
Food preservation	30.00	40.00	23.00	30.60	4.50	10.00
Household appliances	20.50	29.00	15.00	22.00	9.50	14.20
Water pumping	6.00	6.50	2.40	3.50	0.30	0.50
Lighting	2.25	2.44	1.95	2.00	0.85	1.05

Considering the hypotheses mentioned, the matrix of specific consumption of useful energy is projected for the forecast division years and from these hypotheses the corresponding net energy values derive.

The estimate of future consumptions reveals that the introduction of electricity into the supply pattern leads to a reduction in the period 1984–1989 of the electricity as regards the substituted sources. The effect is greater in the high income levels: for the As the reduction is 20%, for the Bs 12% and for the Cs 1%. The annual accumulative growth rates for the period 1984/1994 of specific consumption of electricity for the different income levels are: A = 9.2; B = 8.7 and C = 10.9%. The use of lighting gives high values in the three income levels, but these values decrease towards the end of the period as a result of the incorporation of other uses. A significant penetration of electricity can be deduced even though the penetration criteria are conservative and are based on the behaviour observed of the electrified users polled. The remainder of the energy which could be substituted consists of firewood for water heating, kerosene for food preservation and gas oil for water pumping.

Finally, it is proposed to compare rural users' annual electricity consumption values obtained through projection to 1994 with those corresponding to 1984. This is done in Table 3.9. Bearing in mind the quantities of A, B and C dwellings which comprise U.3 (non-electrified), the weighted average of annual consumption of electricity is 951 KWh.

Table 3.9 Annual Electricity Consumption (KWh/year)

Income Level	1984	1994
A	1278	1673
B	764	1159
C	450*	551

* Estimated value due to the small number of persons polled.

Total Potential Demand

The potential electricity demand of non-electrified dwellings (observe that consumption of the dwellings which do not possess electricity is not considered) is calculated for the horizon year with the object of subsequently establishing the level of coverage which, above this value, the resulting electrification project would reach. Table 3.10 contains the results of the calculation.

Table 3.10 Potential Electricity Demand

Income Level	Number of Dwellings	Specific Consumption (Koe)	Potential Demand		
			Toe	MWh	Structure
A	555	143.87	79.85	928	7.5
B	7574	99.65	754.75	8776	70.7
C	4913	47.44	233.07	2710	21.8
Total	13042	-	1067.67	12414	100.0

In order to determine the power demand, the power of the installations utilized is assigned to each use and is obtained from the information surveyed in polls and data connected with the supply of the most widely known equipment in the market. The values adopted for each type of dwelling are shown in Table 3.11.

Table 3.11 Calculation of Power Demand

Use	Equipment	Power (Watts)		
		A	B	C
Water heating	Boiler	300	300	300
Space heating	Fan	180	180	180
Food preservation	Refrigerator	180	180	180
Household appliances	Iron	750	750	750
	Television	120	120	120
	Washing machine	420	420	420
Water pumping	Pump	400	400	400
Lighting	Lamps	390	320	170

For the purpose of constructing the daily load curves corresponding to single or group users, the incidence of the penetration hypotheses and the information related to habits of use must be considered. For a group of users (more than 45), the power of each piece of equipment should be affected by the penetration coefficient, assuming in this way that the penetration hypothesis is confirmed in groups that would have at least the number of members mentioned. The daily distribution must be adjusted in accordance with the habits of use, which vary in the three periods of the day. In accordance with the values obtained, the maximum power demand is recorded during the night. In addition, the relative difference between the maximum power and that corresponding to the remaining periods of the day is greater in the lower income dwellings (see Table 3.12). In this way the daily load curve of the type A dwellings is the one which shows the least difference between the daily maximum and average power.

Table 3.12 Power Demand for Groups of Dwellings (45 or more users) (watts per user)

Use	Dwelling A			Dwelling B			Dwelling C		
	M	A	N	M	A	N	M	A	N
Water heating	60	60	60	2	2	2	-	-	-
Space heating	-	90	45	-	47	23	-	40	20
Food preservation	168	168	168	126	126	126	42	42	42
Household appliances									
Iron	98	145	216	77	372	170	23	112	51
Television	23	75	103	23	74	102	19	60	83
Washing machine	242	71	8	174	51	5	20	6	1
Water pumping	138	69	69	32	16	16	16	8	8
Lighting	-	-	390	-	-	320	-	-	170
Total Demand	729	1008	1059	434	664	764	120	268	375

M = 6:00 to 12:00 AM A = 12:00 to 6:00 PM N = 6:00 to 12:00 PM

The situation of the isolated user is different. The penetration hypotheses are valueless in this case, since the user in question could probably utilize the electricity in all the uses considered. Nevertheless it has been assumed that for an isolated dwelling it is logical to presuppose a certain rationale in the habits of use in order to use the available power adequately. In addition, bearing in mind that in the face of a surplus of power it is necessary to interrupt the service by means of intensity switches; the capacity of this device will, in the last resort, set the power demand.

4

Description of the Energy Resources

Evaluation of the Hydro Resource

Definitions and Calculations

The hydroelectric potential of a basin can be calculated in different ways, according to the use to be assigned. The Gross Theoretical Hydroelectric Potential (GTHP) is defined as the total power delivered by the water flowing through a natural channel, from a higher elevation to a lower one, without calculating the potential of the tributary watercourses, and admitting that there are no losses of any kind. It represents a theoretically available potential although practically unachievable because of the losses referred to and because of the technical impossibility of utilizing it due to geological, economic, social and ecological incidences. Thus defined, it becomes the index which evaluates the total hypothetical magnitude of the hydraulic power of a given basin.

Since the magnitude of the GTHP of a sub-basin depends on the existing natural differences of the elevation and on the volumes of flow circulating in the stretch being analyzed, the areas of run-off basins, the specific drainages and the above mentioned differences in elevation will be used in the calculation.

If H represents the head of the stretch of stream whose sub-basin is being analyzed and Q the average flow volume circulating through it, the continual power developed would be:

$$P\ (\text{KW}) = \frac{1000\ .\ Q\ .\ H}{75}\ .\ 0.736 = 9.81\ Q.H$$

and the average annual production of energy:

$$E(\text{KWh/year}) = P(\text{KW}).\ 8.760\ (\text{hours/year}) = 85{,}935.6\ Q.H.$$

The value of Q is obtained as a product of the specific flow which has previously been calculated or estimated, multiplied by the run-off area up to the control point of sub-basin or stretch being analyzed.

The following sequence can be used to calculate the GTHP of a basin.

1. Divide the basin into sub-basins in accordance with the pattern of secondary, tertiary and other tributaries of the main watercourse and clarify the stretches which they involve over the main, secondary, tertiary and other courses. Enumerate the sub-basins with a nomenclature related to the basin being studied.
2. Calculate the areas of the sub-basins determined.
3. By means of calculations or estimates, adopt the specific yield for each sub-basin.
4. For each sub-basin, add up all the flows which will pass through its control section.
5. Calculate the differences in levels between the highest and the lowest parts of the stretch of the main watercourse of each sub-basin.
6. Using the first formula, calculate the continuous power of each stretch or sub-basin.
7. Next, carry out the accumulative calculation of powers by sub-basins going from the headwaters to the end of the basin being studied.
8. Using the second formula, calculate the Theoretical Annual Energy at continuous power for each stretch and by accumulation, the total of basin starting from the headwaters to the end of the basin.

It is much more interesting, with a view to planning the electric fitting out of a given region, to analyze the so-called Technical Utilizable Hydroelectric Potential (TUHP) which, by definition, is the one technically feasible to put into effect, even though a certain proportion of it may not be economically advisable at the time of evaluation.

Normally neither the information nor the necessary experience is available for defining the TUHP, so it is usual to resort to methodologies developed for basins which have practically exhausted their hydrogeneration capacity. This allows indices to be obtained which relate the density of the GTHP with a range of TUHP percentages.

The density of the Gross Potential is the quotient of the GTHP of a given sub-basin by sub-area and gives an idea of the gross continuous power of each sq. km. of area, providing an energy quality index of the stretch being analyzed.

The TUHP as a percentage of the GTHP can be obtained, for example, from Table 4.1 given by the United Nations Economic Committee for Europe with information of minimum and maximum technical potentials with regard to the gross potential on the basis of the specific density of the gross potential.

Table 4.1 Calculation of the TUHP

Potential Density (GTHP) KW/sq. km.	TUHP as % of the GTHP
10	0–25
50	0–30
100	5–35
150	10–40
200	15–45
250	20–50
300	25–55
350	30–60

The TUHP is calculated taking into consideration the conventional technologies applied to large, medium and small hydro-energy schemes and dispenses with any classification of them in function of their magnitude. In accordance with the object of this study, Technical Utilizable Hydroelectric Potential on micro-generation scale (TUHPm) is the fraction of the GTHP which is in condition to be utilized by means of setting up micro-power stations—power exploitations of less than 100 KW. As with the TUHP, the calculation of the TUHPm enables the technically feasible potential to be quantified, although without using economic or any other kind of considerations which establish the advisability or feasibility of the exploitations.

The TUHPm has been conceived of as the potential which can be utilized by means of the installation of micro-hydros. Following the calculation outlines of the TUHP as a percentage of the GTHP, the TUHPm is calculated in the same way, for which purpose a percentages table is prepared based on the characteristic parameters which would qualify the energy aptness of the stretch or sub-basin with a view to its energy utilization by means of micro-hydros. When experience recommends or field surveys give grounds for it, the values of the TUHPm can be affected by means of correction or approximation coefficients. These coefficients will depend on hydrogeomorphometric parameters of indices of the basins or sub-basins under study (drainage densities, specific area of maximum slopes).

Taking the foregoing, the TUHPm can be calculated using an expression of the following kind:

$$\text{TUHPm} = P(\text{GTHP})\ C_1\ C_2\ C_3 \ldots\ldots\ldots C_n\ (*)$$

Where P is a percentage obtained by tabulation in function of the Density of the Gross Potential (in KW/sq. km.); and the coefficients C_i are numbers equal to or greater than one and which can likely be obtained by field experience, through survey of pilot areas.

Thus, in cases where it is impossible to obtain these coefficients, their value will be equal to the unit and expression (*) will be reduced to the product of GTHP by P. However, when a study is carried out to obtain a ranking of the different basins or sub-basins as well as the period in which it is hoped to have a picture of their energy quality, the comparisons between them (in other words, the relative values of the TUHPm which could be obtained) will be more significant. In this way, the lower order approximation which might be obtained would not acquire importance, since the calculation methodology is general for all the sub-basins, and therefore the final objective is preserved.

The calculation made for every sub-basin will make it possible to cover the course from the headwaters to the control point of the basin, to accumulate partial values, until the TUHPm for the basin as a whole is achieved.

To obtain the tabulation of the P percentages, on the basis of the Gross Potential Density, the proposal consists of analyzing a sub-basin judged to be representative of the region under study and to carry out a field survey programme as thorough as possible, with field visits to the potential location sites previously chosen through cartographic support, or aerial photography if available.

From the specific analysis of each site surveyed, the Real Potential to be exploited in the sub-basin can be calculated, which subsequently can be related to the corresponding

GTHP. If the hydrographic unit chosen for the field survey could be broken down into other subunits or sub-basins, the modality could be repeated with each of them, in order to be able to obtain new values for the correlation being sought. When it is considered that the values obtained are transferable or can be extrapolated, evaluation of the TUHPm for other basins or sub-basins can be started by simple assignment of the tabulated values, in function of the Gross Potential Density, and possibly of the coefficients C_i which may have been obtained, the value of GTHP of the respective basins or sub-basins being available for the purpose.

Results of the Case Study

Topographical maps were used, on a scale of 1:50,000 with contour lines every 5 or 20 metres, according to the sector, which permitted the water divide (limits of basins and sub-basins) to be drawn with a high degree of reliability. The study area lies within the territorial limits of the Departments of Oberá and Cainguás. But the limits of the basins do not coincide with them. The evaluation also included the basins which are only partially within these Departments, thus resulting in a larger area for analysis. Since these topographical maps date from 1962 and the present situation in connection with soil use and infrastructure is significantly changed in some parts, the ordnance maps of the 1980 census were also useful.

The only geological information available consists of charts of the study area on a scale of 1:50,000 which basically allow visualization of the location and orientation of faults and diaclases in the general geological conformation. These are characterized by a basalt rock basement lying in the form of horizontal strata. Since the watercourses in Misiones flow over this basalt, its analysis for the siting of small sealing structures was left to the stage of visual field reconnaissance. Experience developed in the province on the subject of hydraulic schemes clearly indicates that the basalt rock stream beds provide optimum conditions for the foundation of this type of construction.

The rainfall data available was only analyzed for the purpose of defining the specific yields which were extrapolated to neighbouring basins in order to estimate the average flow volumes circulating in the streams of the study area. The records used for this comparison give annual average values in Oberá for the ordinary period 1952–1980, showing 1,778 mm in Colonia Mártires, 1,879 mm in Oberá, 1,806 in Colonia Guarani and 1,632 in Campo Viera. In Cainguás the rainfall information was extremely scant, records only being available for Campo Grande (1,679 mm, 1952/80), Saltito I (1,955 mm, 1965/80) and Cuartel Rio Victoria (2,105 mm, 1968/78).

The complete absence of historical flow records of any stream located within the departments studied meant resorting to indirect or extrapolation methodologies to estimate the specific basin yields (in liters/sec. and per sq. km. of surface) to be used in the calculation of GTHP. For this the series of average monthly flows were used, published by Agua and Energia Eléctrica corresponding to the streams Piray-Guazu (1964–78), Pirai-Mini (1962–76), Urugua-i (1953–77) and Yabebiri (1951–77). The series with the greatest longitude and therefore the most reliable as regards extension corresponds to the two latter streams.

The Yabebiri shows a specific average flow up to the location of the gauging station (close to Colonia Mártires) of 18.3 liters/sec. × sq. km. This figure was modified, arriving at a specific yield of 17.8 liters/sec. × sq. km. This figure was adopted for all the basins in Oberá.

With the same criterion, analyzing the geographic location of Cainguás with regard to the basins of the streams Yabebiri (nearest) and Urugua-i (furthest away), an evident increase is recorded in the average annual rainfall towards the north-east, from approximately 1,650 mm in Campo Viera-Campo Grande up to 2,100 mm in the zone of San Vicente-Cuartel Rio Victoria. Therefore an estimated specific average flow of 20 liters/sec. × sq. km. was adopted for the basins in Cainguás.

For calculating the TUHPm the following expression was used in this study:

$$\text{TUHPm} = \text{P1} \times \text{C1} \times \text{GTHP}$$

in which P1 is a percentage which appears in the attached table in function of the gross potential density of each stretch and C1 a tabulated coefficient in function of the Linear Gross Theoretical Potential. In this way P1 qualifies each stretch in function of the surface distribution of the Gross Theoretical Potential, while C1 estimates the final value in function of the hydro-energy quality of the main watercourse.

Based on experience and the field studies carried out, the referential values considered for Misiones appear in Tables 4.2 and 4.3.

Table 4.2 Hydro-energy in Misiones

Gross Theoretical Potential Density	
(KW/sq. km.)	P1 (%)
Less than 30	1.00
From 30 to 40	2.00
From 40 to 50	3.00
From 50 to 60	4.00
From 60 to 70	5.00
From 70 to 90	5.50
From 90 to 120	6.00

Linear Gross Theoretical Potential	
(KW/km)	C1 (%)
Less than 50	1.00
From 50 to 80	1.05
From 80 to 110	1.10
From 110 to 140	1.15
From 140 to 170	1.20
From 170 to 200	1.25
More than 200	1.30

Table 4.3 Hydro-energy in Cainguás and Oberá

Cainguás Basin	GTHP (KW)	TUHP (KW)	TUHPm (KW)	TUHPm Density (KW/sq. km.)	TUHPm / GTHP (%)
Guira-i	15904	3167.80	880.50	2.91	5.54
Saltito	18549	3395.60	715.30	1.74	3.86
Pindaiti	2308	346.20	70.70	1.24	3.06
Tamanduá	7919	1398.00	288.00	1.51	3.64
Alegre	18395	3520.90	845.40	1.50	4.60
Acaraguá	3669	637.00	54.00	0.44	1.47
Del Medio	2729	388.30	55.50	0.54	2.03
Sub-total	69473	12853.80	2409.40	1.38	3.47
Oberá Basin					
Acaraguá	24602	4092.00	982.80	1.29	3.99
Ramón	9812	1334.00	239.70	0.69	2.44
Sagrado 1	692	104.00	22.80	1.34	3.29
Sagrado 2	899	135.00	52.50	2.36	5.84
Chico Alferez	3861	579.00	139.00	1.51	3.60
Once Vueltas	13878	1996.00	417.70	1.05	3.01
Mártires Grandes	7785	1168.00	202.40	0.62	2.60
Yabebiri	24375	3504.00	714.70	3.12	2.93
Sub-total	85904	12912.00	2771.60	1.25	3.23
Total Region	155377	25765.80	5681.00	1.43	3.47

The study of the hydro resource was completed with the location on maps of 430 points of interest.

Evaluation of the Wind Resource

It is not possible to carry out the exact quantification in methodological terms of the resources of wind energy in the study region due to the lack of proper measurements. Nevertheless, all the existing information has been used for the purpose of reaching approximate values.

Measurements taken in the local stations and experiments carried out in the Engineering Faculty of Oberá were considered. The nearest station is that of the National Institute of Agrarian Technology (INTA) in Cerro Azul. There the measurements are taken by means of cup anemometers installed at heights of 0.5 and 2 metres from the ground.

The information from the series 1981/85 of data surveyed by INTA was used for evaluation of the resource. The INTA station is located at an altitude of 280 metres above sea level. As the highest measurements were carried out at 2 metres, while the wind generator will operate at a height of 8 metres, the readings were adjusted by a factor of 1.3. The wind generators have been designed so that they start up with winds of 3 m/sec. Therefore, in the measurement sheets the days were identified when the speed of the wind exceeded 8.3 km/hour, at a height of 2 metres.

Results of the analysis are: Between 12 and 15 days a month the winds exceeded the speed of 3 m/sec. with a daily duration varying between 3 and 7 hours. The maximum continuous period with wind speeds less than 3 m/sec. is 7 days. The maximum speed recorded with the durations mentioned is 14 km/hour equivalent, according to the factors considered, to 5 m/sec. approximately. Consequently, a speed range of between 3 and 5 m/sec. has been adopted for the design of equipment suitable for the energy and power requirements of the users.

Evaluation of the Biomass Resource

The province of Misiones is characterized by its subtropical climate, without a dry season, with high temperatures almost the whole year round between 20 and 30° C, with an average of 90 to 100 days of rain per year and total annual rainfall between 1,500 and 2,000 mm. The subtropical jungle, once covering most of the provincial surface, today occupies 1,250,000 hectares and for the most part is degraded by selective exploitation of the species with the highest commercial value.

The economically exploitable area is calculated at about 900,000 hectares of natural forest, while the area of planted forests (with species for paper and cellulose) amounts to 150,000 hectares.

From the energy point of view, the natural degraded forest provides abundant material for firewood. Yield indicators in the production of wood from the natural forest vary according to the zone and the state of woodland. Taking an average yield of 100 cubic m/hectare with an annual production of 10 tonnes/hectare/year as conservative values, a total potential theoretical supply for the province is 90,000,000 cubic m of firewood, equivalent in terms of total theoretical energy to 13,630,000 Toe or 160,000 GWh.

The supply of firewood in the market presently comes from two origins, small clearances and sawmills. The firewood material from small areas is for consumption of the producer or is burned on the spot. Supply of firewood from sawmills located in the outer suburbs of the cities allows the lower income consumers to have access to this fuel. The installed production capacity in sawmills is around 100,000,000 sq. ft./year which in theory produces wastes of the same magnitude as the production. In this way the sawmills generate almost 200,000 tonnes/year of wastes. If the idle capacity and the wastes not recoverable for firewood are considered, the supply of the sawmills comes to about 100,000 tonnes/year of firewood, equivalent to 19,000 Toe/year. Out of this, part is used to improve the sawmills' energy balance, another part goes to the household market and a significant portion is burned outdoors.

As regards reforestation, the average rate is around 15,000 hectares a year, which supplies firewood material of about 850,000 cubic m/year, assuming that 80% is planted in the subtropical forest zone and replaces the most degraded areas. This supply represents in energy terms 130,000 Toe and is the main biomass in the province.

With reference to charcoal production, approximately 50 half-moon type ovens exist distributed throughout San Ignacio, Candelaria and Oberá with an overall production of about 28,000 tonnes/year.

Some introduced species have been studied for their application to energy purposes. *Bracatinga* (rapid growth) for household purposes yields 15 tonnes/hectare/year (2.8 Toe/hectare/year). *Eucalyptus dunni* (longer growth) for industrial purposes yields 30 tonnes/hectare/year (5.7 Toe/hectare/year).

The described resource condition puts into context the area for planning. The 7,000 rural families need nearly 1 Toe per family per year. Through the formal firewood market or direct appropriation, the biomass can adequately cover the requirements.

5

Supply Alternatives and Costs

Choice of Supply Solutions

The supply solutions should reach a large number of rural users within the framework of a development programme for the region. These solutions are expressed through alternative models with different technological and institutional approaches. The historical model supplies to the rural population from a centralized organization. This is from an urban or provincial scale enterprise, which extends its services to the peri-urban and rural areas by the expansion of its medium voltage networks. Based on the experience of the user associations developed with micro-hydros in Misiones, an alternative model is proposed comprising small self-organized systems which use simple technologies of energy exploitation of the natural resources available in the region. In the alternative model, the number of users and the power module of the small systems is adjusted to the social and institutional organization criteria and takes the greatest advantage of the natural resources, with a maximum of 75 users grouped together, and an installed power of 50 KW in each small system.

The Centralized Model

The centralized supply model is structured on the basis of the present method used by the suppliers of the electrical service in Misiones. Consequently, the assembly of this model takes into account the existing infrastructure in the rural distribution system, completing it with the extension of networks at the 13.2/7.6 KV level and maintaining participation of the suppliers up to the meter post at the entrances to the users' property.

The Decentralized Model

The decentralized supply model is the minimum solution arising from analysis of a set of methods of alternative supply based on hydraulic, thermal and wind sources. These alternative supply methods have been adopted bearing in mind available energy resources and technical structure in the region as well as institutional behaviour of the future users.

Hydraulic resource

In general, a gross theoretical hydro potential exists with a power density per unit of surface which is around seven times the power demand of the possible users per unit of surface. In particular, there are various regions with significant exploitable hydro potential on the microgeneration scale within the area being studied.

Misiones has a lengthy experience in the development of small hydraulic exploitations, by specialized scientific and technological terms and from companies supplying component parts. The present state of knowledge provides adequate conditions for a programme to optimize and disseminate the technology.

From the institutional point of view, the experience with micro-hydros is less widespread. Only in recent years have exploitations been developed which supply the user groups. Nevertheless, the questionnaires reveal in general an interesting average at the level of social participation of the rural population and, in particular, an increase in the average when organized for the purpose of supplying electricity. However, the problems of institutional juridical organization, of training and technical assistance, and of operation and maintenance suggest keeping the present magnitude of associations which have a good capacity for self-organized development of this supply solution.

In this context the supply method based on the hydraulic source is that of micro-hydros equipped with Banki type turbines, synchronous generation and electronic regulation with transmission by 13.2/7.6 KV line when the distance from the load centers makes it necessary.

Thermal resource

Among the resources provided by the biomass, wood is the source most widely available. A family industry exists for the manufacture of charcoal intended for urban as well as rural domestic uses. Because of the production scale, the charcoal industry has a low level of incorporation of technology and consequently a low biomass transformation yield. Forestry research programmes about different species are in their first phase of development for energy use—carbonizing of native and introduced tree species and gasification of local wood and charcoal.

Adequate networks exist in the region for the supply of oil derivatives (gasolines and gas oil) backed up by a reliable national production structure. National development exists for the production of thermal engines (Otto and diesel), and there is a good local service of technical assistance and maintenance. Within this context, two motor generators have been adopted as alternative thermal solutions: Generators driven by oil derivatives with Otto cycle engines for isolated users, and with diesel engines for groups of users; generators driven by lean gas produced from charcoal and equipped with Otto cycle engines.

Wind resource

As concluded from the appraisal of the resources, wind in Misiones is less important than hydraulic and biomass, but it does have an attractive potential in some regions. Argentina has widespread experience in the application of windmills, both for electrical and direct power uses and mainly in water pumps. Progress has been made in Misiones in technological solutions for the design of a mill and header adapted to local conditions, and experimental units have been installed and are in operation. Although the production of electric energy with wind generators assumes domestic use of 12 V direct current, electrical uses of these characteristics already exist in the non-electrified rural sphere, fed by the tractor battery. Moreover, numerous domestic appliances have been developed which operate on 12 V.DC as accessories of the automobile industry. Consequently, it was considered interesting to include in the analysis the wind generators based on low torque, three-blade windmill direct current generators and a group of batteries.

Criteria for Handling Costs

The methodological approach posed for comparison of the chosen supply alternatives implies the use of accounting prices in the micro-economic evaluation and analysis of the impact on the macro-economic evaluation. This approach requires analytical treatment of the costs and their breakdown into all those components which are of interest, both in the calculation of accounting prices and for analysis of the macro-economic effects.

For each supply method it is necessary to analyze investment costs and operating and maintenance costs during the period established in the study (in this case, ten years). These allow calculation of the Equivalent Annual Cost of each supply method. Included in this calculation is the useful life of the investments involved. For this purpose, the analytical handling of the costs must be carried out for each of the components (motors, turbines, electrical outfitting of power stations, medium voltage lines) of the supply method which would comprise a unit, from the useful life viewpoint.

Finally, each supply method covers a range of installed power, connected with the concentrations of users and their requirements. During the planning and assembly phase of the supply models considered, efficient methods should be on hand for assigning the proper fitting out solution for each group of users. For this purpose, each of the different supply methods is disaggregated in a standardized, typified series within the range of services which it should cover to meet the different power requirements defined.

The Cost Matrices

The breakdown of costs into their constituent items, and the technological disaggregation of the supply modes into their components lead to the construction of a costs data bank made up of a set of matrices. The investment costs matrices carry in their rows each of the typified components of each supply method; in their columns they carry the total market price, disaggregated into a subset of regional incidence values and a subset of extra-regional incidence values. The operating and maintenance costs matrices carry in their rows all the supply solutions which have differentiated operating costs. Each supply solution occupies ten rows corresponding to the period under study, since increasing energy consumption is forecast from year 1 to year 10. The columns also show two subsets of regional and extra-regional values. Tables 5.1 and 5.2 show the disaggregated costs and their role in the economic analysis.

Table 5.1 Investment Costs

	Extra-regional Incidence
Imported material:	Analysis of effects on the foreign exchange and the trade balance.
Local material:	Transfer of income to other regions and incidence on different branches of local industrial activity.
Use of equipment:	Use of idle capacity in the region, both in the industrial sector and in construction. Transfer of income and effects on branches of local industrial activity for replacement of installations.
	Regional Incidence
Local material:	Effects on basic extractive regional activities and on some industrial activities.
Labour:	Analysis of occupational effects both on skilled and unskilled labour. Relative impact on the industrial and construction sectors.
Overheads:	Regional effects on the services sector.
Taxes:	Necessary for financial evaluation of the programme and for measuring national and regional fiscal effects.

Table 5.2 Operating and Maintenance Costs

	Extra-regional incidence
Purchase of electricity:	Transfer to public service enterprises outside the region.
Fuel price:	Effects on the oil reserves and income transfer to other regions.
Imported material:	Same as investment costs.
Local material:	Same as investment costs.
Capital costs:	Same as use of equipment in investment costs.
	Regional incidence
Local material:	Same as investment costs.
Fuel transport:	Effect on the transport sector.
Labour:	Same as investment cost.
Overheads:	Same as investment cost.

By way of example, the investment costs matrix of the medium voltage lines and transformers in the centralized model is given (1 US$ = 0.8A) in Table 5.3.

Technology and Costs in the Decentralized Model

Supply Alternative: Micro-hydros

The micro-hydro supply method is analyzed disaggregated into the following components: Sealing structures, piping, turbines, electrical equipment, complementary work, medium voltage lines, transformers.

The work was done at a preliminary level of defining the solution of the sealing structures for each exploitation. The definite solution requires a field study in each of the sites, which can only be done once the decision to carry out the supply programme required for the region has been adopted. The profile and height of the sealing structure define the volume of materials and construction cost. Consequently, typification of sealing structures means defining profile geometries which, using conservative hypotheses, would represent the situations which may arise in the definitive solution of a construction in the region under study.

Regulation structures correspond to exploitations in the high zones of the basins and sub-basins, where it may be necessary to 'taper' the micro-hydro in order to obtain power rates higher than the continual power. In this way the use of the resource can be optimized in relation to the requirements evaluated in the site zone. The tapering implies greater height of the seal for producing the storage volume required in the reservoir.

In the study the tapering solution was adopted for exploitations with a module flow between 40 and 200 liters/sec. This range of flow has been sub-divided by size of basin into five levels which correspond to 2, 4, 6, 8 and 10 sq. km. equivalent to modules of 40, 80, 120, 160 and 200 liters/sec. In turn, each level considers four tapering factors (1; 1.33; 1.67 and 2).

In diversion structures the concept of utilization of the most frequent flows (75 to 95% constancy) has first importance, and all that is needed is to increase the depth of water in order to divert it to the engine room. These structures correspond to exploitations in low-lying zones of the basins which have sufficient flows for the power modules brought into play in the study. The diversion structures dealt with have a flow range of 200 to 1,000 liters/sec. in steps of 100 liters/sec.

Table 5.3 Investment Costs Matrix—Medium Voltage Lines

				Disaggregation of the Total Investment Cost at Market Prices												
					Extra-regional Incidence					Regional Incidence						
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Centralized by Nets																
Lines	Mono -1 x 16	Km	20	987.49	16.70	399.00	13.00	63.60	29.45	16.56	73.63	16.56	31.56	33.00	143.80	150.63
Lines	Mono -2 x 16	Km	20	1921.12	33.37	724.40	20.30	140.10	52.20	29.00	160.30	29.00	68.70	58.00	312.70	293.05
Lines	Tri -4 x 16	Km	20	3358.52	66.80	1331.00	27.80	252.60	76.00	33.90	306.60	31.30	131.40	67.70	521.10	512.32
Lines	Tri -4 x 25	Km	20	3714.05	86.70	1511.00	27.80	294.00	76.00	33.90	306.60	31.30	131.30	67.70	581.10	566.55
Transformers	Mono - 5 KVA	Global	25	926.60	86.40	484.75		22.90			53.90		23.10		144.20	141.35
Transformers	Mono - 10 KVA	Global	25	1161.06	122.85	5940.10		26.80			67.80		29.00		123.40	177.11
Transformers	Tri - 10 KVA	Global	25	2233.22	214.65	1155.20		55.10	7.00		130.00		55.80		275.40	340.77
Transformers	Tri - 16 KVA	Global	25	2440.65	244.75	1252.50		60.20	7.00		142.20		60.90		300.80	372.30
Transformers	Tri - 25 KVA	Global	25	2725.33	287.10	1390.50		66.70	7.00		157.50		67.50		333.30	415.73
Transformers	Tri - 30 KVA	Global	25	2938.91	321.50	1482.70		72.50	7.00		171.20		73.40		362.30	448.31
Transformers	Tri - 40 KVA	Global	25	3225.65	366.60	1614.50		79.50	7.00		187.90		80.50		397.60	492.05
Transformers	Tri - 50 KVA	Global	25	3513.16	411.75	1746.50		86.60	7.00		204.60		87.70		433.10	535.91
Transformers	Tri - 63 KVA	Global	25	3800.49	454.25	1881.00		93.70	7.00		221.40		94.90		468.50	579.74

References:

1: Way of supply and its components
2: Classification of the components
3: Unit
4: Life time (years)
5: Unit cost at market prices
6: Imports
7: National
8: Use of equipment in manufacturing
9: Use of equipment in installation
10: Local materials
11: Skilled labour in manufacturing
12: Skilled labour in installation
13: Nonskilled labour in manufacturing
14: Nonskilled labour in installation
15: Overhead costs in manufacturing
16: Overhead costs in installation
17: Taxes

The intention was to define a characteristic sealing profile for regulation structures and another for diversion structures. These sealing structures were adopted on the basis of analysis of 30 sites. This analysis consisted of taking measurements on eight existing structures and 22 new sites studied during the resource evaluation field work (sub-basins Macuco I, II and III). These measurements enabled the profiles to be drawn of the corresponding 30 seals; on the basis of correlations between height and surface of the cut-off wall for each site, the desired characteristic profiles were defined. Finally, alternative construction characteristics were analyzed for the purpose of finding their fields of competence for the flow ranges and the corresponding sealing profiles.

The types of construction considered were earthfill, rockfill, buttress and gravity. Comparison of the investment costs of these construction types for typified regulation structures revealed the advisability of using rockfill for flows of 40 liters/sec. and earthfill in the range of 80–200 liters/sec. with a small penetration of buttress structures in some intermediate models of this range. For the diversion structures the economic calculation showed the advisability of using rockfill structures in the range of 700–1,000 liters/sec.

The investment costs matrix corresponding to the sealing structures comprised 20 typified regulation structures and nine typified diversion structures. Regulation structure costs varied from 5,251 Australes (US$6,563.75) to 16,430.32 Australes (US$20,537.9). Diversion structure costs varied from 6,133.64 Australes (US$7,667.05) to 18,129.52 Australes (US$22,661.9).

The useful life considered for the sealing structures was 50 years.

Piping manufacturers offer their standardized products in commercial series which respond to the regulations commonly in use in Argentina. Piping materials most widely used for carrying water are asbestos-cement, steel and, in smaller diameters, PVC. In recent years fiberglass piping has been introduced into the Argentine market.

For this study the correlation between the commercial diameters of the piping and the flows to be transported was determined first. Secondly, the ability of the different materials to cover the flows was appraised.

For this analysis the price lists of the manufacturers and the average yields of equipment and labour for erecting piping as accepted by the Provincial Administration of Sanitary Water (APOS) were used. On the basis of the results obtained, PVC piping was chosen for flows up to 200 liters/sec. and fiberglass piping for larger flows.

The investment costs matrix corresponding to the piping was made up of nine typified solutions. Piping costs varied from 12.27 A/metre (US$15.34 m) to 131.10 A/m (US$163.39 m). The piping was considered to have a useful life of 50 years.

The development of micro-hydros in Misiones was based on the use of crossed-flow typo turbines (Michell-Banki). This turbine is a hydraulic action machine with partial intake, transverse flow and double effect.

With experience from construction and operation of Banki turbines, the micro-hydros programme in Misiones is at a stage of optimization of the design of the machines with a view to improving efficiency. The yield of the first machines did not reach 50%, but soon after making small modifications to the construction criteria, it exceeded 60%. The best yield level reported in the literature reaches 83%. The Misiones programme seeks, by means of hydraulic laboratory studies with models whose design parameters will be modified, to approach the best yields possible with these machines.

For preparing the cost matrix the present manufacturing and erection procedures of the suppliers of turbines for the micro-hydro programme in Misiones were studied. The study model was T1–200–200 machine (Type T1–rotor diameter 200mm –injector width 200mm), constructed manually. Desegregation was made of all the turbine sub-components, for which an estimate was made of the materials and labour hours, the fitting out required for manufacture, subsequent assembly in the machine shop and erection on the site.

This breakdown of the costs structure of model T1–200–200 permitted discussion of the modifications to the manufacturing process which should be introduced for manufacture in (small) series of standardized equipment. The results obtained were expanded for a group of eight turbines of the standardized series, analyzing the variations in the volumes of materials starting from geometrical changes and variation in qualified labour and use of equipment. On the basis of this set of values, cost curves were drawn which enabled the values to be interpolated for the whole standardized series. The turbine costs matrix was drawn up with 20 typified solutions. Turbine costs varied from 924.53 A (US$1,155.66) to 4,996.12 A (US$6,245.15). The useful life considered for the turbines was 25 years.

The generation, regulation, drive and protection operation of the micro-hydros have been adapted to the solutions which best solve the technical and economic conditions of the problem. Sophistication of the installations and consequently their costs have been graduated on the basis of the characteristics of the load center to be attended. Consequently, typification has been made based on the power demand of the load center, both for isolated and group users. Table 5.4 summarizes the critera of typification adopted.

Table 5.4 Load Center Characteristics

Operation	Isolated dwellings Type C	Isolated dwellings Types A–B	Groups of dwellings, Few users	Groups of dwellings, Many users
Power supplied	1.5 KW	3 KW	4–8 KW	13–20–32–40–64 KW
Generation	Asynchronous	Asynchronous	Synchronous	Synchronous
Regulation	By constant load	By constant load	Electronic voltage and frequency	Electronic voltage and frequency
Drive	Mechanical by wire	Electric	Electronic by wave carrier	Electronic by wave carrier
Protections against racing	No	No	No	Yes

The costs and power of the generating equipment correspond to the highest quality commercial brands which are offered in the local market. For the electronic regulation, drive and protection units the present prices of the micro-hydros were taken, allowing for a reduction in the effect of engineering costs per unit for a programme of manufacture on a larger scale. The investment costs matrix corresponding to electrical fitting out was made up to two typified solutions for isolated users and seven for users in groups. The costs of these installations varied from 279.66 A (US$349.58) for isolated users with 1.5 KW power in the generator, to 5,510.60 A (US$6,888.25) for users in groups with 64 KW power in the generator. The useful life was defined on the basis of duration of the generators adopting 35,000 hours (8 years at 12 hours/day) for asynchronous generators and 50,000 hours (11.4 years at 12 hours/day) for the synchronous generators.

Complementary construction considers the construction of accesses and the engine room. Four basic designs have been contemplated covering the whole range of requirements of the micro-hydros (see Table 5.5). Determination of the costs was based on local prices for common construction work, which varied from 53.10 A (US$66.38) for configuration 1 to 1,132.8 A (US$1,416) for configuration 4. The useful life adopted was 15 years for configuration 1 and 30 years for configurations 2, 3 and 4.

Table 5.5 Complementary Constructions

Configuration	For Typical Electrical Fitting out	Access Construction	Engine Room
1	Isolated users 1.5 & 3 KW	For footpath	Housing made from timber
2	Users in groups 4 & 8 KW	For footpath	Shed made of masonry surface 5 sq. m. Roof steel sheet. Wood openings
3	Users in groups 13–20–32 & 40 KW	Access of light vehicles	As above but with surface 8 sq. m.
4	Users in groups 64 KW	Access of light vehicles	As above but with surface 12 sq. m.

Lines are typified in accordance with the transmission system in single-phase and three-phase, the code being complemented with an indication of the quantity and cross-section of the conductors which comprise the line. The corresponding codes are:

- Mono 1 × 16: Correspond to single-phase lines, 1 phase, 1 wire 16 sq. mm cross-section of the conductor.
- Mono 2 × 16: Corresponds to single-phase lines, 1 phase, 2 wires 16 sq. mm cross-section of the conductor.
- Tri 4 × 16: Corresponds to three-phase lines, 3 phases, 4 wires 16 sq. mm cross-section of the conductor.
- Tri 4 × 25: As above but with 25 sq. mm cross-section of the conductor.

The lines are considered to be equipped with normalized materials and made under project and construction criteria approved by the electrical utility in Misiones. The costs varied from 987.49 A/km (US$1,234.36) to 3,714.05 A/km (US$4,642.56). The useful life adopted is 20 years.

The transformer modules correspond to the normalized series of the National Energy Bureau and include powers of 5 and 10 KVA for the single-phase transformers and 10–16–25–30–40–50 and 63 KVA for the three-phase transformers. Their design, manufacture and erection conform to the utility's current regulations. The module includes the installations for protection and operation (lighting arresters and section switches), the hook-up to the medium voltage line, grounding and items for support and fastening to the post. The transformers are equipped with capacitive compensation for improving the operation of the small isolated systems in start-up and with partial loads. The costs correspond to those explained in the analysis of the centralized model and varied from 926.6 A (US$1,158.25) for the single-phase 5 KVA model, to 3,800.49 A (US$4,750.61) for the three-phase 63 KVA model. The useful life adopted for transformers is 25 years.

The small isolated systems of energy production can be operated and administered by the users themselves. Institutional organization is one of the outstanding aspects which can lead to success or failure of new sources and alternatives to conventional technologies. In Misiones the micro-hydros which supply group users are undertaken through associations. These associations of future users administer the government funds for execution of the work; once this is carried out and started up, an administration consortium is formed to operate and maintain the micro-hydro. All the tasks are carried out under the supervision of a team of professionals and assistants belonging to the Engineering Faculty of the National University of Misiones and to the Misiones Energy Enterprise, who in turn undertake the training of the users and provide technical advice during operation and maintenance.

The Misiones experience shows limitations for estimating the operating and maintenance cost of the micro-hydros, since the existing projects have been used as pilot plants for the technological development of the electro-mechanical components. As a result, it has been assumed that the technology development stage has been concluded. Hence the consortium names one of its members as local supervisor of the tasks of start-up, shut-down, operation control and light maintenance. The local supervisor exercises authority for the control of the association's internal regulations and receives remuneration in proportion to the hours involved. The users of the consortium contribute periodically to cleaning jobs and general maintenance of the installations.

The Centralized Technical Service is a government body which attends all the small isolated systems, covering training and technical assistance to local supervisors, heavy preventive maintenance of installations and attention to emergencies which are beyond the scope of the consortium.

An average cost per KWh considers spares, patrolling and labour required for operation, maintenance and attention to emergencies in a micro-hydro with 20 KW installed power, the result being an average value of 0.034 A/KWh (US$0.0425).

Supply Alternative: Motor Generators with Oil Derivatives

This supply method is analyzed according to the following components: Motor, generator, complementary construction, lines and transformers. These are items of equipment in very wide technical use, both nationally and internationally, so they are dealt with here very briefly.

For isolated users (A, B and C), three outfits were selected, two with Otto engines of 0.9 KW and 1.7 KW generator power (0T–0.9 and 0T–1.7) and one outfit with a diesel motor of 2.5 KW generator power (DI–2.5). For user groups, seven outfits were selected with diesel motors ranging from 4 KW to 50 KW generator power (Series DI–4 to DI–50).

Otto engines are small 4.5 HP (OT–0.9) and 8 HP (OT–1.7) engines very widely used in rural activities. They are single-cylinder, air-cooled, oil-lubricated and rotate at 3,500 rpm. The diesel engine series ranges from single-cylinder air-cooled units to six-cylinder units in water-cooled lines for higher power equipment. Power in the engine shaft covers the range from 6 HP (DI–2.5) up to 90 HP (DI–50). Rotation speed of motors is 1,500 rpm and they are laid out on monoblock units with the generator set mounted on a sled. Specific fuel consumption of the engines varies with the increase in power from 0.170 gr/HP–h for the 6 HP unit to 0.220 gr/HP–h for the 90 HP unit.

Generators are synchronous and self-propelled, having similar characteristics to the units used in the micro-hydros. Ten commercial models were chosen which cover the range from 0.9 to 50 KW. The common complementary constructions have been grouped together with a set of accessory installations which include fuel deposits, drive and control panels and electrical start-up system, grouped into five configurations. Lines and transformers have the same components and costs as those for micro-hydros. Investment costs varied. For motors, the range was from 413 A (US$516.25) for type OT–0.9 (Otto engine with 4.5 HP) up to 4,867.50 A (US$6,084.40) for type DI–50 (diesel engine with 90 HP); for generators, from 318.6 A (US$398.25) to 5,664 A (US$7,080); for complementary construction, from 238.36 A (US$298) for Configuration 1 (isolated users) up to 2,879.20 A (US$3,559) for Configuration 5 (groups with DI–35 and DI–50). The useful life of these components was established at:

- 12,000 hours (2.74 years) for the single- and double-cylinder Otto engines
- 25,000 hours (5.2 years) for the single- and double-cylinder diesel engines
- 30,000 hours (6.86 years) for the four- (or more) cylinder diesel engines
- 50,000 hours (11.4 years) for the generators
- 25 years for the complementary constructions and auxiliary installations.

The operating and maintenance modality adopted is similar to that described for the micro-hydros, when small isolated systems are concerned. Compared to the micro-hydros, such generators require a steady fuel supply and greater care for start-up, operation and maintenance of the thermal equipment. This means more work for the local supervisors and consortium personnel. For calculating operating and maintenance costs, consideration was also given to labour, incidence of fuel consumption and lubricants. Repairs and spares were calculated as a percentage of the annual linear amortization quota of the group of motor generator components. Taking the specific consumption variable according to the power of the equipment, such costs were calculated for each of the ten models adopted in the programme, which varied from 0.2045 A/KWh (US$0.301) for the type OT–09, up to 0.1327 A/KWh (US$0.166) for the type DI–50.

Supply Alternative: Motor Generators with Gas

This supply method was analyzed disaggregated into the following components: Gasifiers, motors, generators, complementary constructions, lines and transformers.

The technological complexity of the wood gasifiers led to the decision to choose for this study the charcoal gasifiers because of their technological adaptation and simplicity in operation and maintenance. The prototype adopted is based on a model developed in Brazil, into which modifications have been made in the cooling system. The gasifier is made up of eight components: Gas generator, cyclone filter, refrigeration by convection, oil filter, oil drain, gas dryer, forced refrigeration and gas-air mixer.

The gas generator is the transverse flow type with small openings for entry of water-cooled air. The material used was naval steel with refractory lining in the combustion zone. The cyclone filters have drainage in the lower part for elimination of ashes and charcoal particles entrained from the gas generator. Refrigeration is carried out with finned coils, 2 metres long. The oil filter has a recipient for gas bubbles, steel wool screen and baffle plates which allow separation of oil entrained by the gas current. For drying the gas, a metal cylinder filled with vegetable sponges is used. Forced refrigeration is carried out by means of a tube radiator with a fan fitted with a 0.25 HP motor. The mixture of lean gas and air is carried out by means of adjustable butterfly valves, operated by an electronic frequency controller. Three sizes of gas generators were studied, corresponding to power ranges of 1 to 4 KW (GAS–4), 5 to 25 KW (GAS–25) and 26 to 50 KW (GAS–50). The costs of the three models varied from 1,243.37 A (US$1,554.2) for model GAS–4 to 2,360 A (US$2,950) for model GAS–50. The useful life considered for the gasifiers is ten years.

The ignition motors available in the market are for use with gasoline, having suitable oversize for operating with lean gas. For the 50 KW system a V–8, 140 HP motor is used. For the 35 KW and 25 KW equipment, the traditional six-cylinder motors are used in lines of 100 HP and 70 HP. These are followed by two-cylinder HP motors which would give an approximate power of 10 KW. The smaller models use single-cylinder 8 HP motors for a rate of 1.7 KW. The costs for the series of five motors adopted varied from 625.4 A (US$781.8) to 7,563.8 A (US$9,454.8) for the model OT–50. The useful life was fixed at four years for the single- and two-cylinder motors and six years for motors with four or more cylinders.

The series used in the motor generators with oil derivatives was adopted for gas generators. These include nine models from a power of 1.7 to 50 KW, with equal costs and useful life. Likewise, complementary constructions are similar to the ones adopted for the motor generators with oil derivatives, replacing the fuel tank with a storage shed for charcoal. Three configurations were chosen, whose costs varied from 238.4 A (US$298) for configuration 1 (GAS-4) to 2,879.20 A (US$3,599) for configuration 3 (GAS-50). The useful life adopted is 25 years. Lines and transformers have the same components and costs as for the micro-hydros.

The modality of operation and maintenance is the same as in the case of micro-hydros with corresponding administration consortium activities and others being the responsibility of the Centralized Technical Service. Certain aspects were taken into consideration for calculating costs. The incidence of labour increases in relation to the motor generator with oil derivatives, since the charcoal production cycle is added. Charcoal consumption in the gas generators was assumed to be 1.2 kg./KWh and the production yield of firewood to charcoal as 6 to 1. Charcoal production was assumed to be the responsibility of the consortium, firewood being purchased in the local market. The rest of the operation and maintenance costs are similar to those of motor generators with oil derivatives.

From the five power modules adopted in the programme, the costs varied from 0.1678 A/KWh (US$0.210) for type OT–1.7 to 0.1189 A/KWh (US$0.149) for type OT–60.

Supply Alternative: Wind Generators

This supply method is analyzed according to three components: Windmill, electrical system and accumulators. The lack of wind resource prevents consideration of equipment which could supply groups of users. Consequently, two models were adopted for individual use, one with 900 W power (Type C users) and the other 2,000 W power (Types A and B users), which are designated AER–0.9 and AER–2 respectively.

The windmill consists of a three-blade, variable header system, with ferdering mechanical transmission and multiplication by pulleys. The blades are made of wood, and the profile is the Wortmann type. This component includes the tower, guys, supports and other sustaining items. The alternators coupled to the windmill are of the type used in air conditioning systems of passenger transport motor vehicles for the AER–2 equipment and the traditional automobile alternator in the case of AER–0.9. The electric panel is equipped with a load regulator, metering instruments and protection fuses. Since periods without wind for more than five days do occur in Misiones, the accumulator bench of batteries has been calculated for a maximum reserve corresponding to that period. When there is no wind for a longer period than the reserve, the batteries can be charged with the motor of a vehicle. This avoids making the installations more expensive. The batteries are of the lead-acid type. For 900 W equipment, four batteries of 100 amp/h each are installed. For the 2 KW windmill, six 100 amp/h batteries have been adopted. Windmill costs varied from 1,660.26 A (US$2,075.3) to 2,141.70 A (US$2,677.1); generators from 318.60 A (US$398.3) to 1,177.64 A (US$1,472); accumulator bench from 283.2 A (US$354) to 424.8 A (US$531). The useful life considered was ten years for the windmill, over eleven years for the generator and three years for the accumulators. Attention to the equipment and the bench of accumulators is the responsibility of the user. Only the costs of repair and spare parts are charged to the Centralized Technical Service, calculated as a percentage of the annual linear amortization quota of the equipment. The operating and maintenance cost of the wind generators comes to 0.013 A/KWh (US$0.016).

Technology and Costs in the Centralized Model

The type and quality of the material considered for this study, as well as the design, manufacture and erection criteria of the components of the rural distribution networks, are those demanded by the provincial enterprise, EDEMSE, which provides the service. The transformers are typified by the number of phases and nominal power. In this way, the set of components selected is the following:

Single-phase lines: (1 × 16), (2 × 16), (2 × 25)

Three-phase lines: (4 × 16), (4 × 25)

Single-phase transformers: 5 and 10 KVA

Three-phase transformers: 10–16–25–30–40–50 and 63 KVA

The configuration of a rural distribution line is built up with different types of supports—terminal, suspension, diversion. The topographical features and other regional peculiarities can assign greater or lesser incidence to each type of structure in the cost of the line. For the purpose of defining a basic configuration which would serve as reference for calculating the costs per kilometer of line in this study, a survey was made of the lines existing in the jurisdiction of the Oberá and Cainguás cooperatives. The computation of the amounts of each type of structure, pro-rated over the total amount of kilometers of line surveyed, allowed the definition of a basic average configuration for calculating costs both for three-phase and single-phase lines.

The costs calculated and the useful life adopted for lines and transformers, are those given in the investment cost matrix in Table 5.3.

The operating and maintenance structure of the electric system in the rural area under study combines the provincial interconnected system operator (EDEMSE) which generates and transmits in high voltage with the commitment to distribute and market it in the rural sphere in medium and low voltage (user cooperatives). For the purpose of defining a simplified operating and maintenance scheme of the system in the area which would facilitate handling the costs, it is considered that EDEMSE provides the entire amount of electric energy which is required, being responsible for the operation and maintenance in the stages of generation and transmission in 132 KV, up to the SET 132/33/13.2 KV belonging to the city of Oberá. EDEMSE forecasts generation on the basis of the thermal power station in the city of Posadas, subsequently the incorporation of the hydroelectric power station at Urugua-i (presently in construction) and finally the purchase of energy from the national system upon start-up of the Yaciretá hydroelectric scheme and the incorporation of

Misiones into the national interconnected network. The Electric Cooperative Limited of Oberá (CELO) distributes and markets the energy it receives in the SET of Oberá, being responsible for the operation and maintenance of the rural distribution system in 13.2 KV. The rural system demands a costly structure for attending to frequent outages of the networks caused by atmospheric discharges and storms with high winds, as well as the metering and billing of each user's consumption in an extensive system with a low degree of utilization.

The operating and maintenance costs in the centralized system were calculated with the real cost of the energy placed in the lines of the 13.2 KV system. The real cost of the energy reflects the free costs of the subsidies originated both by the preferential prices of the sale of energy in block from EDEMSE to the cooperatives, and by the transfer of income between the different categories of users supplied by the system.

The generation and transmission costs were calculated from the disaggregated costs structure presented by EDEMSE, updating the values with the average tariff according to costs (excluding profitability) determined by EDEMSE for the second half of 1985. The generating costs presuppose the dispatch of load from the provincial system, which starts out from the present thermal power stations. Then it incorporates the hydroelectric power station of Urugua-i and the interconnection with the Yaciretá hydroelectric scheme. In all cases it incorporates with priority of dispatch the most economic power station. This analysis allows an energy cost between the EDEMSE and CELO systems of 0.0789 A/KWh.

The distribution and marketing costs are calculated from the Oberá Electric Cooperative, analyzing the costs which belong to the rural service within the total costs of the cooperative and the sales of energy in the rural area within total sales. The rural service participates in 15% of the total costs and 5.7% of total sales. A distribution and marketing cost of 0.1013 A/KWh was calculated for the rural area which is 2.63 times greater than the average cost of the service provided by the cooperative for all the user categories. With these values, the total real cost of the energy (without taxes) in the rural area is 0.1802 A/KWh (US$0.3365) for year 1; it drops to 0.161 A/KWh (US$0.201) as the generating costs in the system become less.

6

Appraisal of Supply Alternatives

Comparison and choice of an electrical supply alternative for the area being studied cannot be carried out if an economic evaluation is not available which allows determination of the cost and impact which the different projects or programmes have on the region. In this sense various methods can be observed which attempt to measure the merits of each project so as to provide basic indications for making decisions.

At the present time several approaches exist and are discussed in academic spheres, being based on both micro-economic and macro-economic analyses. The first approaches, widely developed in Western literature and sustained by international financing entities, have received ample diffusion, having been developed from flow of funds and calculation of updated values. Thus, for the purpose of evaluating costs and benefits of a project for the community, analyses have been proposed through the so-called accounting prices with different suggestions for estimating them. Alternatively, and in the hope of understanding the connection between the project and the economy as a whole, methods have been considered based on the use of input-output models. In this case, a new project is introduced into the economy and its impact on the direct or indirect added value is observed through the technical coefficients of the input-output matrix.

This second alternative offers advantages compared to the Cost Benefit Analysis and becomes particularly interesting in the case of underdeveloped countries for appraising supply alternatives with non-conventional energy sources. Nevertheless, the necessary technical coefficients matrix becomes a definite limitation for using this method. Such a matrix is not available for Argentina or for the province of Misiones. Consequently, this evaluation is based on the micro-economic methods (Cost Benefit Analysis) carried out at accounting prices, and the result of its application will be complemented with the measurement of a series of macro-economic impact indicators at the level of the resulting supply programme.

Appraisal Criteria

The discounted flows method means that the criteria for comparison of alternatives have been defined. In fact, faced with the need to reduce the flows of funds to a single figure, it becomes necessary to apply the updating principles, with the possibility of choosing between the criteria of present net value, internal return rate or variations of them. Appraisal of alternatives results from the comparison of different options, in function of the investment expenses and operating and maintenance costs of each of them. This procedure assumes that the benefits are identical, whatever alternative is proposed.

This study was carried out for a ten-year horizon; however, the useful life of most of the installations differs from that horizon and hence introduces difficulties for appraisal. The useful life of the different components of each alternative varies from three years (storage batteries for the wind generator) up to 50 years (structural work of the micro-hydros).

To avoid calculation of residual values or consideration of reinvestments, the criterion of the Equivalent Annual Cost was adopted. The advantage is that it allows the flow of a project to be taken to an annual value, eliminating the need to assume residual values or reinvestments. The calculation formula admits two variations according to whether or not the operating and maintenance costs of the project have a uniform flow. In the first case the formula used is:

$$EAC = OMC + IC \times (CRF)$$

where:

EAC = Equivalent Annual Cost

OMC = Operating and Maintenance Cost

IC = Investment Cost

CRF = Capital Recovery Factor: $\frac{(1+r)^n . r}{(1+r)^n - 1}$

r = updating rate

n = useful life of installation

If the operating and maintenance costs vary throughout the useful life it is necessary to transform this non-uniform flow into a uniform flow, in the following way:

$$EAC = \sum_{n=1}^{10} \frac{OMC}{(1+r)^n} . CRF_1 + IC\ CRF_2$$

where: $$CRF_1 = \frac{(1+r)^{10} . r}{(1+r)^{10} - 1}$$

$$CRF_2 = \frac{(1 + r)^n \cdot r}{(1 + r)^n - 1}$$

The Alternatives

Comparison of the centralized and decentralized models assumes that the benefits in both cases will be similar. In this way the appraisal is limited to analysis of the costs (both of investment and of operating and maintenance) associated with each of the alternatives. The costs were disaggregated in such a way that it is possible to measure regional and extra-regional impacts, as well as their most important components.

Since serious distortions of the main inputs comprising investment and operation exist in the market, a decision based exclusively on the financial evaluation of them (at market prices) would lead away from a hypothetical optimum path indicated by the real opportunity costs for the region. In this sense, decision-taking should be supported by an economic evaluation (at accounting prices), taking into consideration that the objective of the study is to determine the best alternative from the viewpoint of the community and not of a bidder or individual consumer.

The path chosen presents the difficulty implied by calculation of the weighting factors for estimating accounting prices, since they have not been calculated for Argentina or for the province of Misiones. Hence, on the basis of information from various sources, the accounting prices were estimated for foreign exchange, skilled and unskilled labour, fuels and other production inputs.

Calculation of Accounting Prices

Foreign Exchange

Various formulas have been proposed for calculating the accounting prices of foreign exchange. In this study it was decided to use a formula which involves a certain complexity, in spite of which the necessary information for its calculation could be estimated. The accounting price of the currency has been calculated in accordance with the following formula:

$$SPC = \left[U.\ P_m\left(1 + \frac{TCM}{M}\right) + (1 - U).P \times \left(1 - \frac{TCX - SBX}{X}\right)\right].F$$

where:

SPC: Accounting Price of the Exchange

Pm: Price of the Exchange for Importing (official exchange rate)

Px: Price of the Exchange for Exporting (official exchange rate)

TCM: Tax Collection on Imports

TCX: Tax Collection on Exports

SBX: Exportation Subsidies

M: Total Value of Imports (CIF)

X: Total Value of Exports (FOB)

F: adjustment factor by difference between official exchange rate and theoretical parity of equilibrium

U: weighting factor which depends on the ratio between elasticities of foreign exchange supply and demand.

$$U = \frac{N}{N - E}$$

N: foreign exchange demand elasticity

E: foreign exchange supply elasticity

The difference between the market price of the exchange and its accounting prices was not highly significant, the tendency of recent years being for both values to draw closer. Since the market exchange rate is a single one for exports and imports (Px = Pm), it was eliminated from the formula. A weighting factor was calculated (which had to be multiplied by the market exchange rate to obtain the accounting price of the exchange). The value of this weighting factor was 1.077. Consequently: Accounting price of the exchange = 1.077 × Market price.

Price of Labour

For the purpose of calculating the accounting price of labour, the information obtained from the Permanent Polling of Homes was used. This is a survey carried out by INDEC from April to October each year. According to INDEC, full occupation is that involving 35 or more hours a week, Those who work less than 35 hours a week are underemployed.

The underemployed population can be expressed in terms of equivalent unemployed. The hours of work considered normal in the region under study being known, the hours in fact worked are determined. Subsequently the number of underemployed is multiplied by the following conversion factor:

$$\frac{\text{Normative hours - real hours}}{\text{Normative hours}}$$

This formula enables the difference between the hours which should have been worked and those which were really worked to be calculated, the result obtained being then converted into the number of persons to which they are equivalent. To obtain the equivalent open unemployment rate, the number of unemployed obtained in the previous procedure is divided by the economically active population (EAP). The EAP of the region shows remarkable stability over the last twelve years. It has been maintained at rates varying between 35 and 37%. Of the underemployed population, 51% worked less than 25 hours a week, 32% less than 17 hours and the remaining 17% less than 8 hours a week.

Skilled labour revealed a situation close to full employment, while unskilled labour had a high rate of unemployment and underemployment. The origin of the unskilled labour is centered in the rural areas. Estimating the so-called preservation wage places it about 50% below the income which could be earned in the activities foreseen in the project. However, it was decided not to choose that indicator (0.5) as the weighting factor; rather the values reached were estimated by an adjustment factor whose formula is the following:

$$FA = 1 - 0.5\left[\left(\pi . \frac{V}{H} - \frac{\pi}{2}\right) + 1\right]$$

where:

π = 3.1417

V = Unemployment detected rate

H = Maximum admissible unemployment rate

The underemployment index reaches 3.9 %, while the unemployment index is 4.3%, which gives an open unemployment index of 8.2% and a maximum unemployment rate of 19%, leading to an unskilled labour adjustment factor of 0.62.

Price of Fuels

For calculating the accounting price of fuels, a somewhat different criterion was adopted. Since the difficulties involved in the estimate of an accounting price based on the situation of the domestic oil sector would imply an effort far beyond the scope of the study, it was decided to consider the values from exports made by the state oil enterprise as the accounting prices of fuels. In other words, the opportunity cost represented by fuel exports was taken as the accounting price. In this way, the ratio between FOB refinery prices and the domestic prices (at factors costs) indicates the adjustment index to apply to the total costs of the different types of fuels. The average values obtained are given in Table 6.1.

Table 6.1 Price of Fuels

Fuel	Domestic Price US$/m^3	FOB Export Price US$/m^3	Adjustment Index
Gasoline	147.5	204.1	1.384
Gas oil	129.9	167.6	1.290
Diesel oil	83.4	162.2	1.946
Fuel oil	66.6*	143.5*	2.154

* US$ MT

Production Inputs and Investments

For calculating the accounting prices of the rest of the inputs and production factors, the items of greatest effect and significant importance were taken into account. In view of the variety of components, it was even more complicated to estimate adjustment factors. The items considered were material from basic iron and steel industries, equipment from the construction area (machinery, apparatus, accessories and electrical supplies), construction material, timber, fuel transport and charcoal. In all cases except charcoal calculation of the adjustment factor was based on the application of the following formula:

$$\text{Adjustment Factor} = 1 - 0.5\left[\text{sen}\left(\pi . \frac{V - H}{H^0 - H} + \frac{\pi}{2}\right) + 1\right]$$

where:

π = 3.1417
V = Rate of idleness detected
H^0 = Maximum acceptable rate of idle capacity
H = Minimum acceptable idle capacity

The information necessary for estimating the values of the parameters based primarily on the Industrial Activity Indicators published regularly by INDEC. In the case of charcoal, the adjustment factor arose as a weighting in function of the main inputs required: products of forest activity (70%) and unskilled labour (30%). The result of this analysis is summarized in Table 6.2. The prices at factors costs of the respective inputs multiplied by the respective adjustment factor give the values at accounting prices.

Table 6.2 Price of Inputs

Item	Idle Capacity Detected (V) %	Adjustment Factor
Metal industries	5	1.000
Electrical materials	10	0.864
Construction materials	17	0.781
Timber	25	0.700
Transport	6	1.000
Charcoal	-	-

Planning the Supply Alternatives

Analysis of Spatial Distribution

The previously described feature of the rural population of Misiones as being of high density and wide territorial dispersion poses the problem of the spatial organization of requirements, characteristics differing from those cases where the population appears concentrated in small rural villages. Planning the supply requires prior identification of the size and location of the load centers which would attend to the supply of user groups within reach of a transformer by means of low voltage lines. Hence, the criterion was adopted of structuring each load center with the group of users who live within a radius of 750 metres.

For the purpose of analyzing the distribution of the users within the area under study, various actions were carried out. The existing electric lines were surveyed and the profile of the area served was drawn, covering a distance of 750 metres from it. It was assumed that the non-electrified users living within the area served would be supplied from the existing lines. Therefore appraisal of the models was made outside the area served, so as to provide useful results for the policy-maker in connection with new investments in the sector. The number of non-electrified dwellings was taken from the 1980 National Census of Population and Housing, disaggregated by department (Oberá and Cainguás) and by census fraction within each department. By means of a specially prepared programme, the information was obtained for dwelling categories A, B and C. The spatial distribution of the non-electrified users within each census fraction was based on the existing cartographic data with a scale of 1:10,000 and 1:20,000 produced by aerial photographic reconnaissance. This data indicates the roofs of houses and barns. A direct relation does not exist between the number of covered buildings shown in the maps and the number of users in that area. Nevertheless, it constituted a reasonable indication of the degree of concentration of the population in the area.

The load centers were accommodated and a corresponding number of users was assigned to each of them. A hypothesis of 80% was adopted for the degree of electrification (number of potential users/number of registered dwellings). The study continued with determination of users' potential requirement. The potential requirement of a load center is defined as the product of the number of users of that center multiplied by the weighted power demand per user in the fraction corresponding to the load center and by the simultaneity factor. The weighted power demand is calculated for each census fraction taking into account the power demand of the users in categories A, B and C and the relative participation of each category in the universe of non-electrified dwellings in each census fraction. The simultaneity factor for 45 or more users was defined as the ratio between the weighted power demand of user groups and the weighted power demand of the individual user; a coincidence factor of 0.54 was obtained. A linear adjustment was made between 1 and 0.54, and a constant simultaneity factor was assumed for a number of users greater than 454. With a simple calculation programme, listings were made to codify the load centers by department, fraction and order number and to determine the number of users and power demand for each of them.

The same cartography used for analysis of the spatial distribution of requirements was utilized for the choice of points of interest for micro-hydro installation. The cartography consists of topographical sheets on a scale of 1:10,000 or 1:20,000 (according to the regions) with contours drawn for every five-metre change in altitude. Aerial photography was also used as consultation data which served as the basis for survey of the topographical sheets.

Field work in the pilot basin enabled points of interest to be contrasted with the real natural conditions of the stream in that zone. All the points foreseen were located and in all cases continuous powers similar to or greater than those estimated in the design stage were determined. Determination of the points of interest was made in those zones where contour curves piled up along a stream showed attractive gradient conditions. By means of a stereoscopic magnifying glass, the aerial photograph of the siting zone was analyzed, allowing the chosen point to be confirmed or rejected.

For each site chosen, the flow module of the stream was determined in the probable sealing station by calculating the area of the basin upstream. The utilizable head (H) was defined for two and, in some cases, three levels in function of the length of the piping (L). The pairs of values (H, L) were calculated by reading the development of the level curves in the zone immediately downstream from the site. In correlating resources and requirements for constructing the supply model, the planner thus had alternatives available with which to adjust the mini-hydro fitting out in reasonable piping lengths. When the flow corresponding to a site was less than 200 liters/sec., the cartographic lead was raised 2 metres by the increase in height which the forecast regulation type sealing structures produce. A total of 181 sites were chosen for the study.

Wind and biomass resources were subjected to analysis by zones of interest within the area under study. For biomass, the whole area under study was considered a zone of interest for the use of this resource. For wind, those zones which showed relative heights and favourable orientation for exploiting the resource were considered zones of interest.

Requirements and Resources

In order to analyze the possibilities in connection with penetration of the centralized and decentralized models, each department was divided into regions. This emphasized the comparative advantages of the different supplying methods. The outlining of the regions took into account where abundant hydro resources exist, where the hydro resource is very scarce (and the decentralized solution primarily based on other resources) and where important densities of users are concentrated close to existing networks. Within each region, economic comparison of supply alternatives for constructing the minimum cost decentralized model was made on a smaller territorial scale called a sub-area. A sub-area can range from a single load center to a group of load centers whose power requirement would be within the maximum module (50 KW) used in the study. Thus the spatial ordering of the evaluation considers five units.

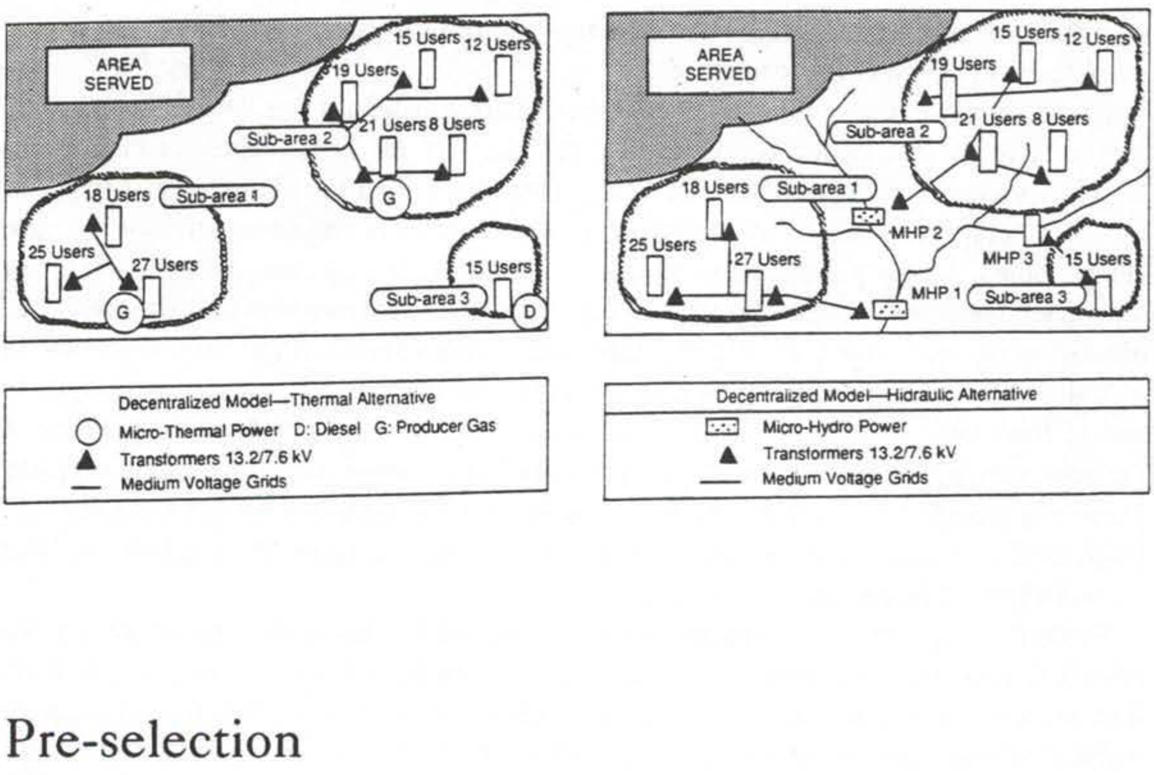
The load center is a concentration of potential users within a radius of 750 metres. Its variation range is 4–75 users with power modules varying from 5 to 50 KW respectively. In this study case, there are 574 load centers with 5,794 users, an average of 10 users per load center.

The sub-area is a group of load centers which defines a space of economic comparison of the different supply methods integrating the decentralized model in order to find the best combination of methods in the area under study. The sub-areas are used as analysis units only during assembly of the decentralized model. Their variation range is 4–75 users, who may be concentrated in a single load center or spread out in 15 or more load centers. Different configurations in quantity of load centers, number of users and relative distances between can occur. The maximum installed power in a sub-area is 50 KW. In this study, 248 sub-areas were organized.

A region is a group of load centers which contain one or several sub-areas; fourteen regions were defined in Oberá and thirteen in Cainguás. A department is the unit of political division in the area. It is maintained both for its relation to the secondary data used (census, cartography) and for information produced for policy-makers. The study area comprises the departments of Oberá and Cainguás, excluding the area which was served by the rural distribution network at the beginning of the 1980s.

Figure 6.1 shows a region with various sub-areas and different means of supplying the load centers which integrate them in a decentralized model.

Figure 6.1 A Decentralized Model



Pre-selection

The supply methods which take part in the decentralized model can be divided into those which can be located within the load center (thermal and wind sources) and those located in the source (hydro resource, relatively far from the load center). In addition, the amount of combinations of supply methods is large. It is thus advisable to establish criteria for their pre-selection.

The thermal and wind solutions located in the load center have a cost which is variable in function to the number of users to be supplied. It is therefore possible to compare the modification of the supply costs with motor generators using oil derivatives, with gas-fired generators and with wind loaders when the number of users varies from 5 to 75 in a load center. It is deduced that the wind generator is not competitive for groups of users. Motor generators with oil derivatives are competitive up to power requirements corresponding to the 15 KW module (approximately 14 users). For fitting out modules of 25 KW and above, the most suitable solution is the motor generator with gas. This preliminary analysis restricts the supply alternatives of the decentralized model to the small thermal and hydraulic power stations.

The small thermal power stations have a noticeable reduction in the EAC per user to the extent that the fitting out model increases, varying from 194 A/user (US$242.5) for five users up to 97 A/user (US$121.25) for 75 users.

On this basis, for those sub-areas that contain two or more load centers, it was considered advisable to compare thermal solutions dispersed over each load center with the thermal solution concentrated in a single generating center interconnecting the sub-area load centers with lines and transformers. In this way the reduction in generating costs can compensate the additional investment costs for distribution of the energy. Even for sub-areas with the same number of load centers, several variations can occur according to the degree of relative dispersion of the load centers.

For the purpose of providing additional pre-selection criteria it was decided to calculate for the different load center configurations the length of the lines (degree of dispersion) which equalled the EAC of both solutions. This was called the 'Equivalent Length of Lines'. A graph was drawn with configurations of sub-areas representative of the case being studied. To analyze the whole field of variation which may arise during assembly of the model, the equivalent line length was calculated for two cases with fourteen users distributed in two and three load centers, respectively; four cases with 26 users distributed in 2, 3, 4 and 5 load centers, respectively; five cases with 44 users distributed in 2, 3, 6, 11 and 15 load centers, respectively. As reference, a graph was also made of the position of the sub-areas which have dispersed load centers at an average of 1 km. In this way, the planner is provided with a graph medium which permits rapid evaluation of the suitability fields of the central and dispersed thermal solutions according to the length of the lines involved in the sub-area being analyzed.

Since the load centers are at a minimum distance of one kilometer, consideration of a central thermal solution per sub-area will only be taken for sub-areas having four or more load centers. Since each load center has a number of users greater than five, the central thermal solution per sub-area will be on the basis of generation with producer gas (gas-fired generators). The dispersed thermal solution will be used for sub-areas having three or less load centers, and each center will be supplied with oil derivatives when it requires installations for 15 KW or less and with gas-fired generators for installations of 25 KW or more. The dispersed thermal solution can be assigned to sub-areas with more than three dispersed load centers only when the degree of center dispersion is high according to the graph.

Assembly and Choice of Supply Model

For each region in which the area under study was sub-divided, the solution obtained for the decentralized model was compared with a planned solution by means of extension of networks from the existing lines. For all the regions, the solution of the decentralized supply model had the lowest economic cost.

The results indicate a participation of 36% of the hydraulic solution and 64% of the thermal solution (in which 59% corresponds to gas generators and 5% to oil derivatives), for the total area under study. The greater penetration of the thermal solution is explained by the strong concentrations of users in the zone of the main ridge belonging to the area being studied, in which at the same time there is a relative lack of exploitable water resources.

Appraisal of the Alternative Supply Programmes

Investment costs were calculated with and without the distribution networks in medium voltage for ease of comparison of the costs per unit of installed power with the costs of similar installations at national and international level. Financial evaluation of the resulting programme indicates investments in the amount of 6,064,413 A (US$7,580,179), 52% of which corresponds to the micro-hydros, 44% to small thermal power stations with gas-fired generators and 3.5% to diesel motor generators.

In spite of the predominance of the decentralized model in the minimum cost solution defined for the area under study, it was advisable to analyze the overall results of the programme on the assumption that supply would be carried out by means of the extension of the existing rural networks.

A fixed service quota, the added value tax and the capitalization of shares per KWh consumed (in the case of distribution cooperatives) must be added to the values applied to energy consumption, to make up the price to the user. An average energy price of 0.0531 A/KWh (including the service quota, VAT and capitalization) has been taken in this analysis. If this value is compared with the earlier one, it can be seen that the average tariff in force in the rural area represents only 25% of the real cost of this service. Thus, taking into account the series of consumptions forecast for the first ten years, the annual operating and maintenance expenses per user vary from 22.20 A in year 1, to 50.60 A in year 10. The present value for the 10-year period with a discount rate of 8% is 239.71 A per user. Considering that the programme foresees supply for 5,794 users, the resulting updated value of the operating and maintenance costs with subsidized prices is 1,388,880 A (US$1,736.100).

In comparing the alternative programmes at accounting prices, the lower total costs can be seen resulting for the decentralized model with a noticeably higher difference (11.9%)

than that which occurs when comparing market prices (2.69%). On the other hand, if a comparison is made at market prices with subsidized tariff, the centralized supply method by networks becomes the best alternative for the area being studied.

The difference between the investment costs of the alternative supply methods is remarkable. In fact, the investment costs of the decentralized system exceed those of the centralized system by about 70%. This difference is compensated by the lower operating and maintenance costs of the decentralized system. For the updating rate of 8% the annual saving in operating and maintenance expenses which the decentralized alternative implies (417,951 A) enables the additional investment (2,550,947.93 A) to be recuperated in a period of nine years.

By way of sensitivity analysis, the results were compared by region at accounting prices of the equivalent annual cost of the centralized and decentralized models assuming a minimum operating and maintenance cost of supply by networks.

This minimum cost would be the result of adjusting calculation of the rural service unit cost of the Oberá Electrical Cooperative, with the hypothesis of expanding the service to all the non-electrified dwellings existing in the area served. This hypothesis of the minimum assumes expansion of the sales without adding operating and maintenance costs in the distribution and marketing stage.

Under the hypothesis analyzed, penetration of the centralized system reaches 18% of the users. This penetration substitutes preferentially the thermal solution whose participation is reduced by 17 points, while the hydraulic solution is reduced by only 2 points.

The Macro-economic Effects

The Cost Benefit Analysis permitted appraisal of the different alternatives within the traditional project analysis approach, in other words, comparison of the flows of discounted funds valued at market and accounting prices. The results arising from micro-economic appraisal are necessary information for choosing an energy supply programme, but they should be complemented with a vector explaining the effects of each alternative of the most outstanding macro-economic variables.

The results of the study have shown that the supply of electric energy to depressed rural areas requires active government action to persuade, speed up or make this supply possible through financial, fiscal, tariff or other mechanisms. Consequently, the development of supplying systems which are characterized as being social projects rather than production projects means that the policy-makers must have access to detailed information explaining the virtues of the project for the region.

In the study, the data bank and the appraisal quantified the following parameters:

- Local labour investment cost
- Local added value/investment cost
- Foreign exchange/investment cost
- Fuel consumption/operation and maintenance cost (oil derivatives)

- Investment cost/total cost
- Unskilled labour/investment cost

These indicators can be calculated both on the total costs and on the investment and the operation and maintenance costs.

A significant difference in terms of percentage does not exist between the centralized and decentralized systems as regards foreign exchange, local added value and local labour. The differences existing between the various manners of decentralized supplying are significant. Motor generators need four times the foreign currency requirements of micro-hydros, while the local added value of the former is five times lower than that of the latter. Other indicators which greatly favour the micro-hydros are those showing the percentages of skilled and unskilled labour. It is important to stress the different intensity of investment costs over total, updated costs: 40.4% for the centralized system lines and up to 91% for fitting out the micro-hydros.

The operating and maintenance costs of the different systems and fitting out styles show extremely significant differences. The local added value of the decentralized alternative is double the percentage corresponding to the centralized system. Percentagewise, the local labour contribution is almost three times higher and the fuel cost is four times lower. On an average the operating and maintenance costs of the decentralized system reach a sum of 350,516 A a year, while the centralized system runs an annual cost of 768,467 A. Updated costs for a 10-year period and with a rate of 8% reach the amount of 2,357,993 A in the decentralized case and 5,156,473 A in the centralized system.

The importance of the local added value in the case of gas-fired power stations is worth noting, taking into account moreover that in accordance with the resulting fitting out, gas-fired plants represent 77.5% of the operating and maintenance costs of the decentralized system.

Taking into account that if a 10-year period is considered, the total cost of the centralized and decentralized systems reach similar magnitudes (8,400,000 and 8,700,000 A respectively). The impact indicators contribute new elements for taking decisions, since they enable the direct effects of each alternative on regional activity to be quantified.

It should be emphasized that this analysis is limited from a theoretical point of view, since it does not take into account that the useful life of the alternatives is different, but it does allow an element of judgement to be approached which otherwise would not appear. Thus the development of micro-hydros and gas-fired plants would mean that 45% of the total costs would remain in the province, 58% of which would be locally-contributed direct labour.

It is evident that the micro-economic indicators enhance the analysis and allow substantiation in decision-making. Both the gas-fired plants and the micro-hydros double the direct local added value and employ a significantly higher percentage of labour.

7

RETAIN: The Second Stage

The provision of electricity is often perceived by both governments and rural people as an essential ingredient of social cohesion and rural development. But it is often difficult and expensive to supply electricity to dispersed rural people. Decentralized electricity supply systems, particularly those based on hydro-electric potential, offer a well proven and technically viable option that can also be the least costly alternative in specific locations. But such decentralized systems are often not able to compete with the electricity provided by centralized national and state power systems because of preferential subsidies and other forms of support that the centralized systems enjoy. Furthermore, central energy authorities are often reluctant to consider decentralized supply systems when comparing technical options.

This chapter investigates two common problems: First, the legal, institutional and financial mechanism by which more rural people could be supplied with electricity within existing budgetary constraints by using a combination of centralized and decentralized supply systems; and second, how successful HMPP programmes carried out on a limited scale can be successfully expanded or replicated over a wider area in order to have a more significant impact.

Rural electrification programmes based on centrally generated power that is distributed through medium tension power lines have developed many stable institutional arrangements. All the necessary tasks (analysis, allocation of resources, design, implementation, operation and maintenance) have been standardized. This enables efficient implementation but has the disadvantage of attaching more importance to technical and financial parameters than to wider developmental objectives. Furthermore, such standard systems are only able to meet the needs of a relatively narrow range of rural conditions and needs. Decentralized systems on the other hand have often been characterized by more anarchic institutional arrangements which have the virtue of experimenting with a wide variety of technologies and approaches. But this diversity forms a barrier to the further expansion of such decentralized systems. The lack of suitable management systems, specific financial funds and institutional arrangements explains the failure of decentralized systems despite their proven economic and technical viability.

The key questions are therefore how decentralized systems can be incorporated into a common framework so that they can be given equal weight in the consideration of alternatives and how such systems can be built, operated and managed with the greater efficiency of centralized programmes.

Objectives and Methodology

The competitiveness demonstrated by the HMPP in the rural electricity supply study in Oberá and Cainguás and the availability of a technology which was sufficiently proven in demonstration units set up in the region have posed the challenge to find a strategy for expanding this supply solution on a larger scale in Misiones. Hence, the specific objectives of the second stage of the RETAIN research project were:

- to establish the potential size of the market for micro-hydro installations in Misiones Province of Argentina,
- to investigate the financial, legal and infrastructural arrangements required to expand the provision of electricity to the rural households of Misiones by means of micro-hydro installations,
- in consultation with government and local institutions and suppliers, to develop a plan for the organization and management of a programme to expand and maintain the supply of decentralized electricity systems in Misiones Province,
- to provide a monograph describing the methods and results of the research and underlining those aspects that are of relevance to other developing countries.

The objectives were achieved by diagnosis and the development of a normative plan. The diagnosis has four components. In the first component of the diagnosis, a brief socio-economic characterization of the region was made for directly approaching the issues connecting rural people with electric energy. The large statistical information obtained during the first phase of the study was reprocessed in order to analyze in detail the potential production applications of electricity and rural people's payment ability. Such issues were reconsidered in greater depth due to their incidence on the energy and power requirements which must be met by the HMPP. Also taken into account were the financial solutions which may be proposed for supporting the investments required by the micro-power plant expansion plan. In the first phase studies, the requirement was focused on household applications of electricity.

The second diagnostic component was evaluation of the experience at the central grid. Analysis was made of the rural electrification experiences on a national, regional and local range in order to identify the causes for the success and failure of central grid programmes. The first element examined was the real cost of this supply. The second concerned the current legal, administrative, financial and technological activities involved in this form of supply.

In determining the costs of rural electricity supply, attention was given to:

- the system of subsidies to the provincial electricity department from the national and state government;
- financial and other contributions from the national level departments of energy, science and technology;
- the potential use of special funds for regional development by the electricity supply authorities;
- the allocation of activities and costs between rural and urban electricity supply within the electricity department to identify hidden costs and cross subsidies.

The diagnosis of the activities of the electricity department identified the scale and content of the various tasks required for the implementation of the existing rural electrification programme. Special attention was paid to the financial aspects of this programme since constraints came up which are common to every technological alternative (either conventional or non-conventional) when the objectives pursued imply the solution of development needs which are not expressed as solvent demands. The analysis was centered on the subsidies in the centralized system and on the householders' response to the payment plans used for performing the works. The information gained from this part of the study was used to design the activities and institutional arrangements required to implement an expanded programme of decentralized supply and will enable more realistic proposals for integrating the two technical options within the planning process.

The third component was evaluation of the hydroelectrical micro-power plant experience over a ten-year period in Misiones. The institutional and normative issues in force were reviewed. The economic aspects of this stage were the development costs incurred up to the adjustment to the demonstration units currently in operation. Attention was given to establishing what actions are currently undertaken that are essential to the outcome and which might be difficult and/or expensive to provide in an expanded programme.

The determination of the size of the market for micro-hydros in Misiones was the fourth component. Micro-hydro potential and the specific location of electricity requirements were identified for the whole of Misiones Province based on the results obtained in the earlier project. These allow the precise conditions of water basin quality and electricity needs to be defined in which micro-hydro options are likely to be superior to other decentralized options (such as gasifiers and diesels) and the central grid. Census data and mapping techniques can be combined with such descriptions to estimate the number of micro-hydro installations likely to be required in each department.

The size of the market was defined in terms of number of HMPP and related investment costs, according to maximum and minimum hypotheses which take into account both the HMPP comparative advantages and the constraints which may arise regarding their mass application.

The analysis was completed with national and bordering countries' demands which, in terms of equipment, works and/or technology supply, may fall on the company and institutions taking part in the expansion plan.

On the basis of the earlier diagnosis, a plan will be developed for the integration of decentralized electricity supply options in the province. An iterative process is envisaged in which an initial plan devised by the researchers is adapted in the light of discussion with the participants. The normative plan would address issues such as the legal framework for such supply options, the roles to be played by the various financial and technical organizations involved in implementation and the main technical characteristics of an expanded programme.

The plan formulation must include the analysis of the costs of marketing; site selection; system design; the transaction costs of getting the legal, financial, technical and material inputs to sites; trouble shooting and adaptation of specific installations; supervision and quality control; follow-up and maintenance.

Special attention will be given to how the decentralized option would be integrated into the existing national and provincial energy institutions and how the various forms of opposition might be anticipated and overcome.

The plan defines the sequence of steps that would need to be undertaken and the structure of the implementing organizations, including those responsible for the design and production of hardware technical assistance, training of staff, the execution of civil and installation work, maintenance and finance.

It is expected that the production of an expansion plan would provide insight not only to the problems of integrating micro-hydros into the thinking of rural energy planners but also to the problems of expanding successful pilot programmes into full-scale operation. Furthermore, it is hoped that the process of formulating the plan would provide the necessary inputs and catalysts to ensure the implementation of the plan in Misiones Province.

8

Energy and the Rural Population

Rural Area Population

From the socio-cultural viewpoint, Misiones shows the co-existence of two cultures coming from Europe and Asia in addition to native ethnic groups which are at present true minorities. At the beginning of national organization in the 19th century, the territory of the present province came under the jurisdiction of Corrientes Province. Towards the end of the same century and in view of the imminent transfer to National Government jurisdiction (*Misiones federalization*), the Corrientes Government sold the greater part of the territory to 29 persons. After federalization, the first successful official settlement programme was put into practice; Ukrainian and Polish families settled in measured areas of the Apostoles farming colony in the south. Settlement was successful and soon more families arrived in Azara, San Jose, Profundidad and Yerbal Viejo.

The great immigration push overflowed government capacity since the available public lands were totally occupied, and only those purchased lands were privately owned. Hence, the new settlers followed a disorderly pattern in establishing themselves.

Towards 1915 the occupation front reached approximately as far as Oberá and the cultivated mate had almost completely done away with the wild mate resources. The 1914 census assigned 53,536 inhabitants to Misiones; 70% of them resided in rural areas, and 38% were of foreign origin. The foreign population was made up of Austrians, Brazilians, Russians, Paraguayans, Italians, Germans, Frenchmen, Swedes, Finns and Swiss. In 1919 the Eldorado, Puerto Rico and Montecarlo settlements were founded by private initiative. Several groups of Germans, some coming from Brazil and others from Europe, settled in the Higher Paraná private settlements.

By 1947 the occupation line had greatly advanced on the Higher Paraná, parallel to the coastline, going as far as Dos de Mayo in the center and bordering the Higher Uruguay up to Monteagudo. The uneven occupation of the province is fundamentally accounted for by the success obtained by the Higher Paraná private settlements and the weakening of the official initiatives regarding settlement in the center and in Higher Uruguay.

By the fourth National Population Census, settlement in the province was complete as far as its most essential aspects were concerned. Population now exceeds 246,000, and the provincial growth rate is higher than the national rate. Foreigners make up to 26% of the population and their number is increasing; they do not come from Europe but from bordering countries. Misiones not only attracts foreign immigrants but also domestic migrants.

After becoming a province in 1954, although it is still one of the most rural provinces of the country, Misiones is no longer capable of retaining its native population which has started to migrate to the large urban centres of the country. By 1965 both official and private settlements had lost their initial push, and the north-east occupation now takes place in a disorderly manner. The soil degradation in the south forces the children or grandchildren of the original European immigrants to move north-east in search of more suitable lands and they occupy the available ones spontaneously. They are joined by emigrants from Brazil and Paraguay.

Rural Producer Energy Supply System

The rural producer energy supply chains have an institutional structure in which national and provincial public and private organizations and companies take part. In Misiones there are four different types of supply circuits. One is the supply of liquid and gas fuels in which the provincial government has no participation. Its circuit, up to the end user, is under the control of national-scale public and private enterprises with provincial private enterprises participating in the consumer distribution step.

A provincial private enterprise participates in the national gasohol programme as a supplier of anhydrous alcohol, and the provincial government promotes this activity through a special committee created in the Economy Ministry. The Empresa de Energia de Misiones Sociedad del Estado (EDEMSE) has been trusted, among other powers, with managing the supply of natural gas by pipelines, but the national pipeline network is not yet supplying Misiones.

The supply of firewood and charcoal is carried out in a market having informal characteristics, with a high degree of self-supply for domestic consumption of rural producers and the participation of private sectors in the supply to farming industries. The provincial government controls these supply circuits through the Wood and Forestation Undersecretariat of the Ministry of Ecology and Renewable Natural Resources.

The electric energy supply is controlled by the provincial government, through the Ministry of Public Works. It has delegated management of the public utility, concession grants and regulation to EDEMSE. However, a large part of the industrial sector electric energy requirement is supplied by self-production means, particularly in the cellulose-paper industries which have a large enough quantity of biomass to produce the electric energy required by them.

The purchase, generation and transmission of electric energy performed in the provincial system is in the hands of Electricidad de Misiones Sociedad Anonima (EMSA), in which the majority interest belongs to the province, and there is a National Government holding. As for the private sector, EMSA not only has the concession for running the Provincial Interconnected System but it is also in charge of distributing and commercializing electric energy in the province's capital city and in several inland towns for a total of 62% of the end users.

In distribution and commercialization there participate a number of electricity cooperative societies organized by the users themselves. Although the cooperatives only service 38% of the end users, they cover the greater part of them.

The sector relations between the provincial and national government are kept up through the State Energy Secretariat, either directly through its different component undersecretariats or through the Consejo Federal de la Energia Electrica (Electric Energy Federal Council).

The development of new energy sources, which are incipient supply sources, is conducted by policies promoted by the National Energy Secretariat and with the participation of EDEMSE and Misiones National University. Particularly in the field of Hydroelectric Micro Power Plants there acts the Centro Regional de Desarrollo de Microcentrales Electricas (CREDMHI) in which the three institutions are copartners.

Figures 8.1, 8.2 and 8.3 show the relationships and participants of the different supply circuits.

Figure 8.1 Misiones Province: Electricity Sector

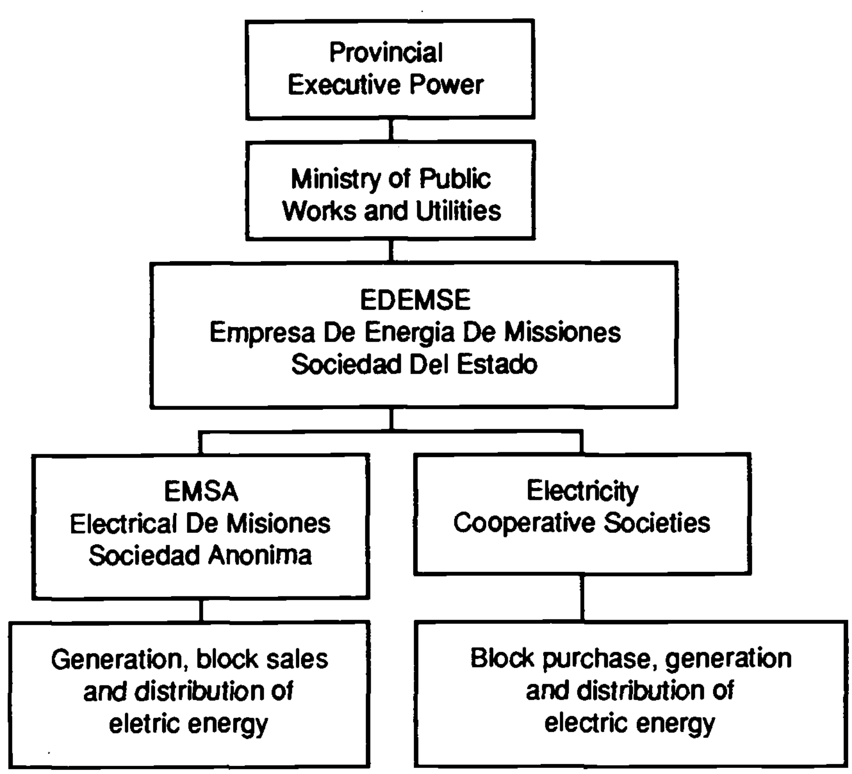


Figure 8.2 Petroleum By-product Sector

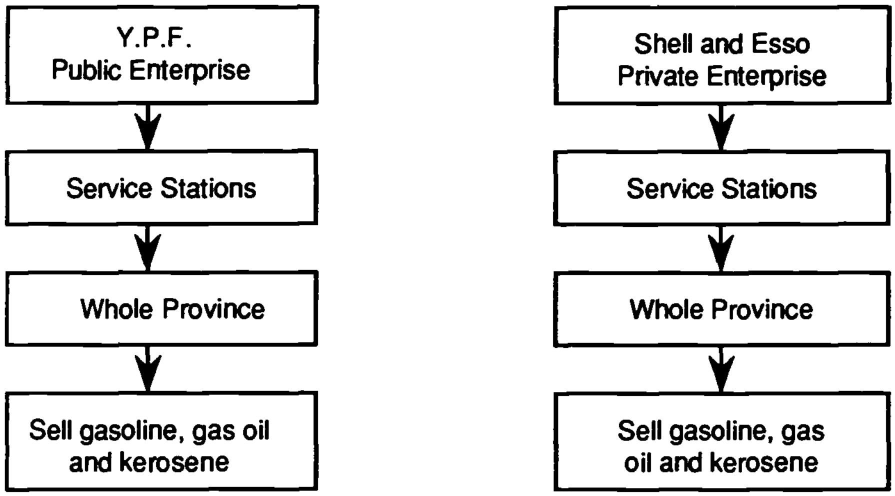
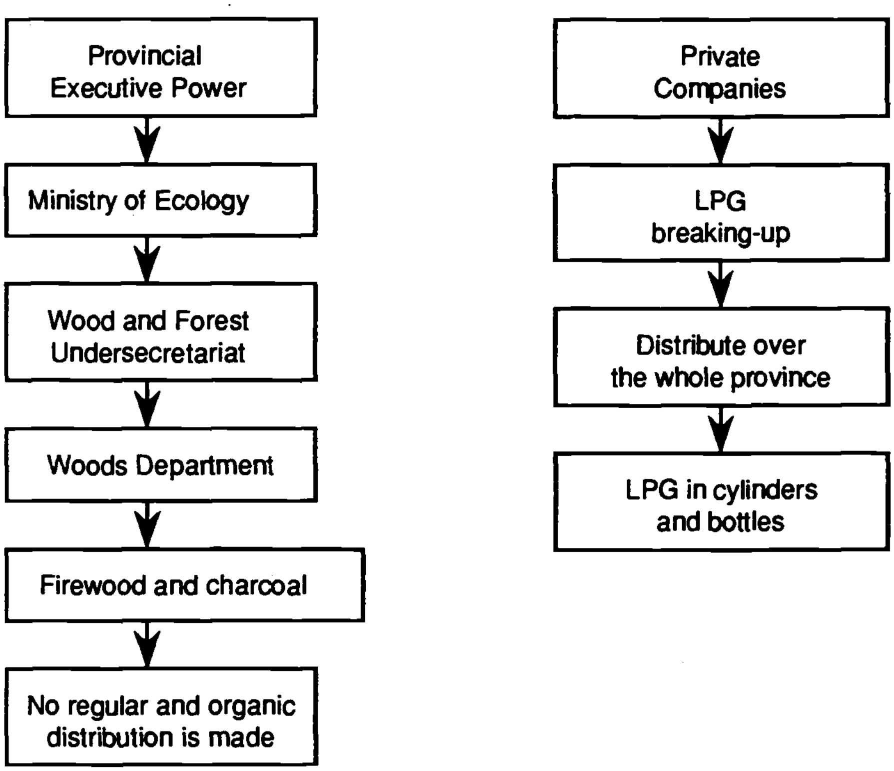


Figure 8.3 Firewood, Charcoal and Liquefied Petroleum Gas Sectors



9

Rural Electricity Supply Networks

National Electrification Plans

In Argentina two national rural electrification plans have been carried out. The first plan was carried out between 1970 and 1975 whereas the second one was executed between 1978 and 1981. A third plan was formulated but never put into effect.

The first plan was carried out almost exclusively through the electricity cooperative societies. The National Energy Secretariat performed the technical control of the projects and works executed. The financial contribution proceeded from the Interamerican Development Bank (40%), the National Energy Secretariat (FEDEI, 20%), users and cooperative societies (20%) and Banco de la Nacion Argentina (20%); the latter also acted as the financial agent of the plan. The cooperative societies had to adhere to strict regulations such as performing the feasibility studies and technical projects through consultants, and adjust to Interamerican Development Bank's procedures for international bidding.

The Banco de la Nacion in its capacity as financial agent granted credit to the cooperative societies on 15-year amortization terms plus three free years. The balances were updated in accordance with the variation of either the Farming Wholesale Prices or the U.S. dollar (whichever was lower), less 50%. The interest rate was 6% p.a. There was, consequently, a direct subsidy from the National Government equivalent to 50% of the updating of due balances.

The plan was completed because of voluntary participation and the free decision of future users who joined the plan and had to sign agreements with the cooperative societies to participate and pay the corresponding contributions. The agreements stipulated financing guidelines which were identical with those imposed by the Banco de la Nacion to the cooperative societies. The rural producers who did not join the plan were exempted from any commitment even though they profited from a higher valuation of their land due to the nearby passage of electricity lines. That is to say, the plan did not contemplate any improvement tax. This means that, in spite of the undeniable public interest aroused by the plan, the lack of an appropriate definitive legal frame caused it to be transformed into private interest works paid by the users themselves.

Some provincial governments granted the cooperative societies actual promotion credits in order to obtain successful results in the works carried out in their areas.

The plan was deemed successful. The Interamerican Development Bank's contribution amounted to US$41,000,000; 23,427 km of lines were installed for 13,334 users and a 3,847,318 hectare area was electrified. This first plan went to electrify what in Argentina is called the 'Humid Pampa' which is the wealthiest rural area, having the highest productivity, income-producing and population density rates.

The same costly rules of international bidding, publications and consultants were also applied in the second plan. The cooperative societies were not given the alternative of an official body.

The areas to be electrified were peripheral regions mainly situated in the north-east. They were areas of lower relative development, and the greater part of their farming producers had very low payment ability or none at all. No legal frame was established for this case as public works.

Financing amounted to 90% of the investment figure, the sources thereof being the Interamerican Development Bank (50%), the National Energy Secretariat (25%) and the Banco de la Nacion Argentina (25%); 10% of the investment amount had to be given as advance payment met by direct contributions from the users. The financial terms of the loan granted to users were harder than in the first plan, for though the 15-year amortization period plus three free years and the 6% interest rate on unpaid balances were kept, the 50% reduction in the balance updating was eliminated and the adjustment index was the General Level Wholesale Price.

In this plan, 23,655 km of lines were built for 17,786 users, and a total of 3,855,392 hectares was electrified.

Although from a structural viewpoint the plan was successful, from the financial viewpoint it led 97 cooperative societies to a critical situation which has been partly solved by government action (Act 23.006 of 6th December, 1983) but whose consequences still persist. Criticism of the financial proposal points out that the funds granted by the Energy Secretariat were directed through the Banco de la Nacion on contract terms which are typical of a trust business. The financial situation of the second plan was aggravated by a national economic policy which had negative effects on production and, consequently, on the regional economies of the areas electrified. The electricity cooperative societies are convinced that the Interamerican Development Bank's contributions only covered the greater costs incurred on account of the bidding procedures used in relation to those which would have taken place had the works been performed by an official body. That is to say, international credit was applied to subsidiary and dispensable aspects of rural line construction. This was made worse when the National Government subordinated the social objectives of rural electrification to the ruling conditions of international credit. Table 9.1 shows the balance of the rural electrification situation in Argentina, based on data obtained from the Energy Secretariat, 1984. At that time, it was estimated (on the basis of data from the 1969 Farming Census) that there were 540,000 farming operations in Argentina. It arises therefrom that only 11.82% of the rural property is electrified. Of this, only 7.8% is serviced by government whereas 92.2% is serviced by cooperative societies.

Table 9.1 Rural Electrification in Argentina

Reference	Number of Users	Lines (kms.)	Serviced Area (hectares)
Before First Plan (Coop)	17,942	8,960	2,940,780
First Plan	13,334	23,427	3,847,318
Second Plan	17,786	23,655	3,855,392
1971–1983 Period (Coop)	9,812	11,208	2,038,698
Provincial Companies	5,000	6,000	1,000,000
Total	63,874	73,250	13,232,188

Foreign Finance Sources

The international and regional banks are public institutions made up by a number of countries and have basically developed after the Second World War. They include the International Bank for Reconstruction and Development or World Bank, Interamerican Bank for Development and other regional banks. In the energy investment field, these banks were originally directed to financing thermic or hydraulic electric works. With the energy crisis of the 1970s they started to finance projects related to other sources, such as petroleum, natural gas, charcoal and non-conventional forestry projects. Simultaneously, technical assistance programmes were directed to energy planning and to the solution of particular energy problems in developing countries.

In the late 1970s, 60–70% of the total funds committed came from the World Bank, 20% from the African Development Bank, 10% from the Interamerican Bank for Development and 2–3% from the Asian Development Bank.

The World Bank oriented its financial assistance, over the 1981–1985 period, as follows: 57% to electric energy, 31.3% to petroleum and gas, 6.4% to charcoal and 4.7% to renewable sources (biomass). The future trend is to increase the assistance to renewable and non-renewable sources at the expense of electric energy, which will continue being the most important destination, however. The World Bank is trying to create an associated organization exclusively dedicated to energy financing which would allow it to channel much more significant funds into this sector. Its credit and loans are oriented to financing material and equipment exports of industrialized countries. However, with adequate negotiation, part of it may be used for local currency expenses with a reasonable margin of protection against international prices.

Regional banks, such as the IDB, have much more flexible policies which are more suitable for developing countries; their credit is generally intended for assisting buyers. There is a greater negotiation power, in terms of prices and other sales conditions. However, the IDB recently started to apply, in the energy sector, similar policies to those sustained by the World Bank. Thus, loan granting is at present conditioned by prior approval of sector policies, particularly the ones related to tariffs. In the last meeting of Ministers, this policy was approved for all the sector loans.

Loans for specific projects are those intended for financing one or more projects or project phases which are entirely defined at the time of the bank loan approval. The specific project must be defined in terms of its physical and technical individuality; that is to say that it cannot be divided or fractionated without affecting its essence or the rationality of each of the independent elements. It is understood that a specific project is normally totally defined when its cost, preliminary design and technical, financial, legal, economic and social feasibility have been proved; its purposes, objectives and goals are known; its planning and designs have been so worked out that the cost of the project may be adequately estimated.

Global loans for multiple works programmes are intended for financing a set of similar works, physically independent from one another and the feasibility of which does not depend on the execution of a certain number of said works. Normally, the rural electrification projects are financed according to the global loan method. The physical and financial dimension of the programme has been basically determined taking into account the execution capacity of the entity which would carry out the operation, the execution period of each work or project as individually considered, the resource availability and other factors which are substantially independent from each of the specific component elements since the latter, taken individually, have a small physical magnitude. The independence of the specific elements allows a multiple works global programme to be divided as long as the elimination or indefinite postponement of some specific elements may be assumed without its affecting the soundness of the other elements of the programme.

Global loans to development institutions are granted so that they may supply resources, through the granting of subloans, for projects whose financial needs are not, in the bank's opinion, sufficiently large to justify the latter's direct action. The implementation of any loan of this nature is governed by a 'set of rules' agreed on by the bank and the borrower; these stipulate the procedure for implementation and define certain aspects such as beneficiary eligibility standards, subloan terms and conditions, subloan design and evaluation factors, sectors or projects which may be assisted with the credit and other parameters and/or restrictions governing the application of the loan resources and the local contribution.

Mixed method operations contemplate a combination of the above-mentioned loans in view of the characteristics of a certain project.

Bank participation in the rural electrification project finanĉing is designed to promote an increase in the availability and security of the electric energy supply in order to efficiently meet the long-term growing requirements. It is intended to encourage the long-term planning aimed at the efficient application and development of electric energy sources. It promotes the fixation of tariff structures based on efficiency and financial considerations, taking into account potential users' needs for electrification benefits as economic development and social advancement. Further, it strengthens the electric energy institutions by furnishing them with technical assistance to improve their planning and management of the operating, financial and technical aspects.

In order to secure bank participation, the plots of land must be so divided that there may be a good degree of rural property general density per kilometer of primary line to be built (one user per km. for suitable load density). The beneficiaries to be connected thereto must contribute a minimum amount of the total investments to be made on rural electrification during the building period. The organization applying for an IDB loan for financing rural electrification and responsible for the project execution and progress may be a private or a government company running public utilities. A government company may act through the Ministry of Agriculture, the Energy Secretariat, the National Bank or the agency in charge of development. Responsibility for project execution and operation may be delegated to one or more companies rendering electrical services and/or user associations, the project coordination and financial control being by a committee and/or a financial agent. The interest rates in force are about 8%. The loan repayment terms range between 10 and 15 years with three free years.

Export banks are intended to promote and assist material and equipment exports from industrialized countries to the developing ones. They improve the competitive conditions for the companies of the country of origin in international bidding and agreements. They are in some special cases, national banks, such as the U.S.A. Export-Import Bank; in other cases they are special credit lines for exports channelled through banks having a wider scope of action. The financial terms offered by these banks are halfway between those of the international and private banks, but their credit is exclusively intended for vendors, and, consequently, the buyer's negotiation capacity is reduced.

Many private banks sprang up after the energy crisis of the 1970s. They provide funds in trade terms for energy investments. Charged with recycling petrodollars, they have the most unfavourable financial conditions as regards interest rates, amortization and free periods. On the other hand, credit negotiation is quicker and has less additional cost than in the international banks.

Supplier credit is directed to buying material or equipment from the supplier offering the credit. This is normally the most unfavourable condition in relation to payment terms and interest rates as compared to the other sources mentioned.

Other international sources of bilateral or multilateral nature, dedicated to technical and financial assistance, are generally oriented to carrying out studies and small magnitude projects in areas having a very low development level. Among the multilateral sources, there can be mentioned the United Nations Development Program (UNDP) and OLADE's Special Fund. Among the bilateral ones, there are the development agencies of industrialized countries—USAID, SIDA, GTZ, SAREC, CIDA.

Local Finance Sources

The Internal Fund Generation (IFG) is the surplus generated by the sector companies as the difference between their current income (determined by the sales volume as multiplied by the corresponding tariffs) and their current expenses (salaries, fuel purchase, energy and power purchase, taxes, materials and supplies). Thus, it is made up of the profit obtained from commercial activity plus the fixed asset depreciation. In Argentina, license agreements stipulate, in theory, profitability levels of 8% above the tariff base. The profitability concept in public utilities is understood as the need to generate funds which not only maintain the system at its present condition but also expand it to new non-electrified areas or improve the available service. So, profitability and expansion funds are the same thing.

A widely debated point is whether or not the electricity tariff should generate all the funds required for system maintenance and expansion. It is generally accepted that the tariff must generate the necessary resources for the current expenses and fixed asset depreciation. This should be a nationwide approach so as to ensure compensatory mechanisms covering the regional differences (different cost structures as in the Misiones case) and guaranteeing the application of uniform tariffs all over the country.

Assuming that a tariff structure is achieved which maintains the systems in their present operating condition, there is still the question of whether an 8% profitability rate is enough to fulfil this purpose. It has been proved that there is a very close relationship between the required profitability rate and the system growth rate. Consequently, in a highly developed system where growth is merely vegetative, the required profitability rate would be very low. On the other hand, in less developed systems which require much expansion starting from low capitalization levels, the profitability rate would be extremely high. In the latter case, which is in accordance with the reality of most service users in Argentina, it is necessary to analyze other finance methods for new investments and reject the alternative of basing the system expansion on the tariffs applied to the users of pre-existing installations.

The National Treasury interacts with a series of Special Funds pertaining to the energy sector according to the surplus or deficit occurring in relation to the annual investment plans. Within the provincial scope, there are contributions from Rentas Generals del Estado (revenue office) which finance part of the investments on this scale using resources from federal tax co-participation. From the legal viewpoint (Section 9 of the EDEMSE Creation Act), the resources derived from royalties, which correspond to Misiones for the exploitation of water resources by means of national works, must be directed to electricity investments by way of capitalization of the provincial assets.

Although there is no powerful medium- and long-term financial market from which the electricity companies may borrow funds for their investments, it is possible to obtain assistance for developing local suppliers. Official banks, such as BANADE and COFIRENE, act as the operators of foreign finance lines and are in a position to channel local savings for providing local suppliers with a financial competitiveness equivalent to that of foreign suppliers.

Special Funds were created in Argentina in 1945, for the purpose of financing the investments required by the electricity and fuel sector. They are, at present, the following:

- Fondo Nacional de la Energia, 1945 (National Energy Fund)
- Fondo Nacional de la Energia Electrica, 1960 (National Electric Energy Fund)
- Fondo Especial de Desarrollo Electrico del Interior, 1960 (Special Inland Electric Development Fund)
- Fondo de Combustibles, 1967 (Fuel Fund)
- Fondo Nacional de Grandes Obras Electricas, 1971 (Large Electric Works National Fund)
- Fondo Chocon-Cerros Colorados-Alicopa, 1974 (Chocon-Cerros Colorados-Alicopa Fund).

The original philosophy of these funds was that of causing a transfer to the income obtained through the sale of non-renewable sources (petroleum and natural gas) to the development of renewable sources (hydroelectricity). Later on, when large magnitude works (Chocon) were started, it was considered that the scale change had to be covered by special funds. Finally, the funds have been conceived to be the local counterpart of the foreign loans and have stood as guarantee for the financing of the large magnitude works undertaken as from the 1970s. Only one fund, FEDEI, has been conceived as a redistributor of income from the central area towards the interior.

There is a specific fund for covering the higher costs demanded by Misiones on account of its being an isolated system. Fondo Ley was created in 1983 (Act 22.938 Fund) and makes up for the gap between current income and expenses; consequently, it is not directed to investments. The different electric consumption growth rates (ranging nationwide from an average of 5 to 11% p.a.) in Misiones results in the income growth rate being lower than the exploitation deficit growth rate. Consequently, the deficit portion which can be covered by Fondo Ley is increasingly lower.

On a national scale, the Ministry of the Interior manages the Fondo de Desarrollo Regional (RIF Regional Development Fund) which is made up of contributions from federal tax co-participation. On a provincial scale there exist the Fondo de Electrification de Misiones (1967, Misiones Electrification Fund) and the Fondo Energetico Provincial (1973, Ex Piray Guazu, Provincial Energy Fund), both of which have been formed with resources derived from the province and are intended for financing investments. Collection of the provincial taxes which constitute these funds is temporarily interrupted and is deemed to be resumed when Misiones obtains the benefits of being connected to the Very High Voltage National Network. Figure 9.1 shows the energy sector funds, the legal instruments which gave rise to them and the appropriation of the corresponding percentages.

From the point of view of resource management, it can be noted that the Energy Secretariat is highly centralized and applies the funds to the works performed by the companies under its own jurisdiction. Consequently, the provinces have no participation at all in the decisions related to the application of 87% of the total investment resources to which they have contributed through tax payment. The Federal Electric Energy Council undergoes a double restriction: first, due to its advisory capacity, it makes no decisions and, secondly, it is never consulted in connection with the application of funds, excepting the FEDEI.

There derives from this administrative fact a strong lack of balance in the national electrical infrastructure. Companies depending on the national government, due to the nature of their jurisdiction, apply the funds to the development of large-scale generation and very high voltage transmission. On the other hand, provincial subtransmission and distribution works and even the generation works in non-interconnected systems have very few resources: the electricity funds only give the provinces 13% of the resources. Table 9.2 gives a short legal and administrative summary of the Special Inland Electric Development Fund (FEDEI).

Figure 9.1 Special Funds for Energy Supply

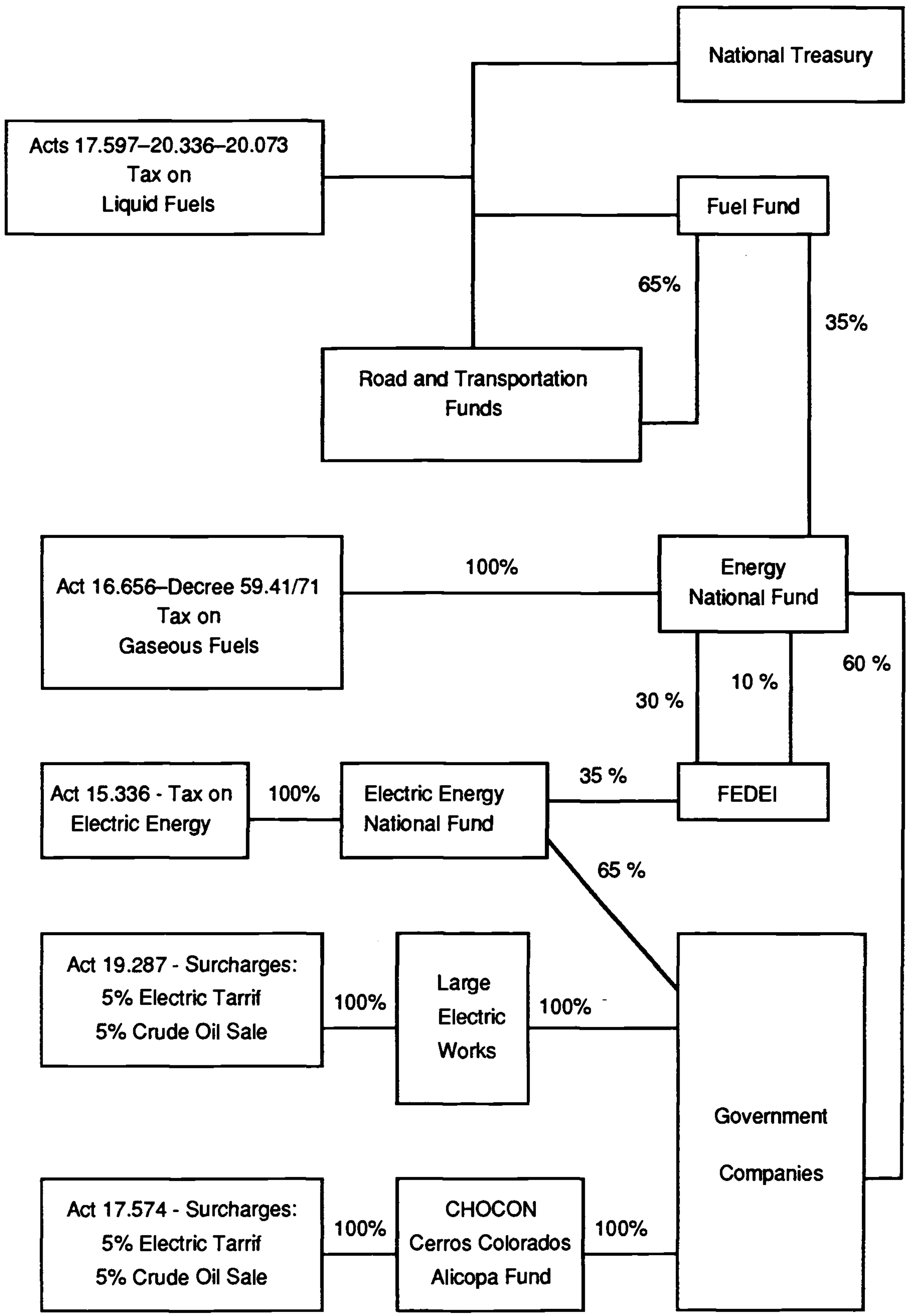


Table 9.2 Special Inland Electric Development Fund (FEDEI)

Creation Instrument: Section 32 Act 15.336	Date: 9/15/1960
Legal purpose: To provide the mechanism through which the national government shall contribute to the development of power plants and electrification networks by giving contributions and granting loans to the provinces and granting loans to the municipalities, cooperative societies, associations and private companies rendering public electrical services.	
Applicable Resources:	Average annual account (1978–1987)
1. Contribution of a minimum 10% of the National Energy Fund proceeds	US$31,132,166 (40.35%)
2. Contribution of 20/35% of the National Electric Energy Fund proceeds	US$37,243,666 (48.27%)
Other Resources Foreseen by the Act and Not Regulated or Used:	
1. Those surcharges as may be stipulated by the National Executive Power on the electric tariffs applied in the Federal Capital City and Greater Buenos Aires	
2. National Treasury contributions	
Destination According to Creation Act and Amendments Thereto:	
1. Contributions and loans to the provinces for renewal and enlargement of power plants and construction of electrification networks. In accordance with Act 15.336, the contributions are allotted by resolution of the Energy Secretariat on the proposal of the Federal Electric Energy Council. Said allotment is made through distribution indices. Misiones Province is entitled to a total distribution index of 5.28%. The loan terms are: 6% p.a. as a minimum interest rate and a maximum 15-year amortization term.	
2. Loans to municipalities, power plant associations and cooperative societies for the construction of power plants, distribution networks and complementary works. The loan terms are the same as for the provinces.	
3. Loans to private companies rendering public electrical services for the enlargement and improvement of their power plants not exceeding 2,000 KWA. Financial terms range between 8% and 3% for the interest rate and from 5 to 10 years as regards the amortization term.	
Destination over the 1978/87 Period (Annual average):	
Financing for Misiones	US$2,954,132 (3.63%)
Financing for provinces (excluding Misiones)	US$52,995,329 (68.68%)
Financing for the private sector	US$6,992,807 (9.06%)
Undistributed balance	US$13,991,268 (18.13%)

If the relationship between the other Special Funds and the FEDEI, over the 1978–1987 period, is analyzed, several considerations arise. The NEF's contributions to the FEDEI and the NEEF (which indirectly flow into the FEDEI) have been strictly kept to the *minimum* stipulated by law, thus clearly indicating the greater institutional influence exerted by the national companies on the Energy Secretariat in relation to the provinces. NEEF's contributions to the FEDEI have been, during the two periods considered, lower than the percentage stipulated by law. The only fund whose management generates large carry-forwards every fiscal year is the FEDEI. The crediting of these in subsequent years implies a loss of about 10% of the total amount of the fund's resources at constant values.

The only contributions which the Energy Secretariat submits to evaluation before transferring them are those coming from the FEDEI. The contributions from the remaining funds for the national companies are not submitted to any evaluation either prior or subsequent to their being transferred. There are no records of the specific applications given by the national companies to the contributions transferred to them from the different funds. While legislation (Act 15.336-FEDEI) provides for income transfers (derived from the application of taxes on electricity consumption in these areas) to be made from the Federal Capital City and Greater Buenos Aires to the interior, the Energy Secretariat does not implement them. Instead, over the 1984–1987 period, NEF, NEEF and CCCAF contributions of the same magnitude as the contributions made to the provinces through the FEDEI were passed on to SEGBA.

Legal Background

After the difficult experience with the Second National Plan, the electricity cooperative societies have insisted on the National Rural Electrification Law promoting this branch of the public electrical services and providing a legal background appropriate to the reality of Argentina's rural development. Until 1988, however, no specific national laws had been made to that effect.

Although legal deficiency is a restriction on the development of national electrification plans, the provinces having a higher level of farming exploitation, such as Buenos Aires, Cordoba and Santa Fe, have specific legislation for their own rural electrification programmes. This legislation declares rural electrification to be of provincial interest and appoints organizations having competence in the preparation and execution of the plans. In this aspect, provincial governments have used different criteria to delegate the main responsibility to the agriculture or public works authority. Legislation also creates Specific Funds for financing the plans, indicating the sources which make them up, and imposes obligatory contributions on the owners of beneficiary estates, in areas for which plans have been approved. The competent authority is allowed to determine which property may be exempted from the payment obligation.

The economic aspects are generally coincident and propose that 100% of the investment costs relative to each property be covered on the owner's account. (The works cost apportionment criteria for the payment of the beneficiaries' compulsory contribution consider one common component for the trunk lines and two components which are proportional, one of them to the property area and the other to the required power.) Limitations and exemptions are determined in terms of the property production capacity with a contribution limit being set in terms of the property purchasing value. Financing the compulsory contribution is done with Special Funds, the province's contributions, special credit lines from provincial banks and property owners' direct contributions. Since 1988, Buenos Aires Province authorities update the payment instalments in accordance with specific indices of the farming activity carried out in the area where the works are erected. (Decree No. 749/88, regulatory of Decree-Law No. 10.069/83).

In the organizational aspect it is indicated that other participants, besides the competent authority appointed by law, may contribute to the electrification plans. Municipalities, cooperative societies, consortiums and private associations are particularly mentioned to this effect.

Rural Electrification Plans in Misiones

The first important effort towards meeting the unsatisfied electrical energy needs of Misiones rural inhabitants started in the second half of the 1970s when Misiones joined the second National Rural Electrification Plan. Out of the thirteen cooperative societies having concession areas for rendering electricity in Misiones, seven took part in the National Plan; they were Concepcion de la Sierra, Leandro N. Alem, Obera, 25 de Mayo, Cainguás, Libertador San Martin and Montecarlo.

Between 1974 and 1977, a census of potential users was carried out within the higher interest districts in the concession area of the cooperative societies, and 3,288 subscribers were found. In 1981, once the works were completed, the number of subscribers had gone down to 1,798; there was 45% desertion among the rural inhabitants interested in getting connected to the networks.

This desertion was due to several causes. First was the high cost per user arising from the technological and contractual methods used for carrying out the works. Inappropriate financial terms of the loan against a background of general policies favoured the value of money over the value of farming production. An ineffective sector policy approach led to operating the works as if they were in the user's personal interest, barring access to the service by the population having a lower income level. This led to underutilization of the installations.

The Banco de la Nacion Argentina, in evaluation of the results attained by the second plan, underlined several aspects (see Ferrari, Luro and Rodriguez). Investment in equipment and electric energy use were predominantly oriented to household consumption whereas productive applications were minimal. The electrical equipment incorporated by the producers in the three years following the plan is scarce and demanded an amount equivalent to 70% of the amount used in the electricity network installation. After the networks started to operate, a gradual incorporation of new users among the population having no electrical service and residing next to them could be observed. For better management the cooperative societies need to overcome their own deficiencies, adopt uniform accounting and management control plans, develop simple maintenance record systems and arrange for more rational tariffs.

From the profit and loss viewpoint, this plan immersed the cooperative societies in a difficult financial situation, the magnitude of which assumed different dimensions with each of them. Default was incurred, over the 1980–1987 period, in the amortization instalment and loan interest payments, and intense negotiations were carried out at the national and provincial levels in order to obtain solutions to the problem. Assistance measures were taken, which, though insufficient, helped to improve the cooperatives' financial situation.

Under these circumstances, Montecarlo and Oberá Cooperative Societies managed to overcome their financial difficulties and to regularize their payments to the Banco Nacion, with an acceptable degree of instalment collection from the subscribers. The other five cooperative societies, which had a very high cost per user or a low degree of instalment collection, could not overcome the financial difficulties. In 1987, they negotiated with the Banco Nacion to regularize the debt on more favourable finance conditions. Refinancing agreements called upon the cooperative societies to make a greater effort towards the collection of users' instalments.

In order to cover the gap between the money collected from users and the amount owed to the Banco Nacion, the societies have used funds from their exploitation surplus and from amounts they charge their users on account of shares. Cainguás and 25 de Mayo in particular have included in the tariff a fixed monthly amount intended for the payment of the rural electrification credit instalments.

From the viewpoint of rural area electrical infrastructure improvement, the second National Plan has been successful since it added 2,170 km. of Medium Voltage lines (60% of the total rural networks operating the whole province as of 1987) and 18.3 MVA in transformer power (which was later expanded due to the joining of new users to the networks already built). From 1984 the financial problems affecting the cooperative societies began to be solved; while the value of the amortization instalments to be paid by the users started to decrease in real terms, the interest in carrying out new electrification plans in the province were rekindled.

The initiative is now taken by the government. With general revenue contributions and FEDEI resources it performs a series of works within the jurisdiction of EMSA and the cooperative societies. The Special Inland Electric Development Fund contributes to support electrical infrastructure investments in the province through non-refundable contributions to their governments and soft credits given to the local cooperative societies. The result indicators at this stage show the building up of 727 km. of lines having 7 MVA of transformer power and a total of 1,090 new users. The new density is estimated at 2 users/km of line. Table 9.3 lists the results.

The table enables planners to approximate the tasks which remain for rural electrification in Misiones. Over the decade, the mean building rate was 360 km/year. The electrified surface is 3,600 sq. km. The area with productive capacity (farming, cattle-raising, forestry) is 19,000 sq.km. The length of required lines is 19,000 km. for the productive area and 14,000 km. for the population yet to be served. Required connections in the already serviced area are 12,000. The time required to meet these needs is 40 years (at the present rate). Investment costs for lines is US$75,000,000 and for connections is US$10,000,000.

Table 9.3 Rural Electrification Results in Misiones, 1977–1987

Result	1980	1981–87
Rural households	61,161	
with lighting	10,018	
with generators	1,204	
with no electricity*	49,939	
with no service	14,000	12,000
outside service area	36,000	35,000
New rural users to existing networks		2,000
New rural users to new networks		1,000
Length of lines (kms.)	2,900	3,625
Users/km.	1	1.5

* Includes some suburban households

Technological Aspects

Rural electrification technology in Misiones has been determined by national criteria which have conditioned the application of financing funds for building them up in accordance with the Technical Regulations and General Specifications for the *Rural Electrification Project and Execution of Works* made by the National Energy Secretariat (1978). These regulations, in turn, were supported by the long experience developed in urban distribution networks and, particularly, in the rural areas of Buenos Aires Province where the *Regulations on Installations, Specifications and Construction Types for Use in Rural Electrification* had been in force since the 1960s. In this way, criteria and standards tested in greater socio-economic development areas were extrapolated to different social, economic and cultural conditions. Ten years of persistent electrical service in rural areas despite scanty resources and expensive technology still left many unsatisfied needs. Hence, it was necessary for the Energy Secretariat to revise the technical criteria applicable to rural electrification works by means of Resolution S.E. No. 696 dated December, 1987.

The Resolution took note that the electrical application prevailing in the rural area was the domestic one. Load density, energy consumption and load factor of the installations were very low. No suitable information was available concerning the actual energy requirement levels of future users prior to constructing the works. It was necessary to drastically reduce the costs of rural system investment, operation and maintenance so that the available resources could permit the electrification rate to be accelerated.

Based on these considerations, the Resolution introduced three important improvements in the technological concept of the rural electrification works and in their operation. It authorized the utilization of single-phase systems with ground return (MGR), utilization of steel conductors and supply of electrical energy without metering. MGR systems are widely used by electricity companies in southern Brazil, in the areas bordering Misiones.

CEEE of Rio Grande do Sul, CELESC of Catarina and COPEL of Parana run over 35,000 km of rural lines with the MGR systems with nearly 100,000 connections.

Costs of Misiones Rural Electrification

A complete survey was carried out on the investment costs of the main rural electrification plans performed in Misiones, the results of which are shown in Table 9.4. It is noted that the mean costs per km of line are slightly higher in the second Plan (IDB) than in the 1984/87 Plan. Naturally in the second Plan the higher mean power per user represents a larger proportion of industrial users and, consequently, a higher relative weight of the three-phase lines than of the single-phase ones which, in combination with a very low user density, renders a very high mean cost per user.

Table 9.4 Investment Costs in Misiones

Plan	Power Range KVA/km	User Density US$/km	Power Density KVA/User	Cost/User (US$)	Cost/km (US$)
IDB	5–10	0.64	8.27	6,798	4,486
IDB	10–15	0.89	12.64	6,435	5,706
84/87	5–10	1.47	5.74	2,795	4,098
84/87	10–15	1.69	7.26	2,916	4,941

In the alternative evaluation report, made in RETAIN's Phase 1, new networks were planned and their costs calculated on the basis of line construction standard values. To the cost calculations were added the low voltage extensions (average US$300/user), and the meter installation (US$100/user) which had not been computed in Phase I (since this cost was common to all alternatives involved).

The network extension mean costs used in RETAIN correspond to an area having a large density of potential users of whom 80% are supposed to be supplied and whose power requirements are limited to domestic applications. For this reason, the cost per user is lower than in the mean references of the built or planned works where a portion of industrial users is computed (which increases the power requirements) as well as a lower user density. Consequently, a larger share of line falls on each user.

On the basis of the different data sources, the total mean costs to the user of the rural network extensions in Misiones with partial utilization of MGR systems with aluminium alloy conductors for domestic applications of low power density range between US$4,200 to 5,000/km for 1.5 user density and US$2,800 to 2,000/km for 2.5 user density. From experiences with MGR systems with steel wire, it is possible to predict that, as long as their use is maximized, the unit costs for the described case can be reduced to 50% as a minimum investment level.

In the provincial electrical system there are different groups rendering services at each stage. Generation and transmission stages are the responsibility of EMSA, and distribution and commercialization are mainly handled by the cooperative societies. The total generation and transmission costs incurred by EMSA average US$0.100/KWh. Such a high energy cost is accounted for by the fact that the energy is generated in an isolated system, circumscribed to the provincial market, having a thermic type generation plant with liquid fuel-operated, high specific consumption machines. Misiones has no gas pipes and is located more than 1,000 km away from the nearest fuel distribution centers. The cost in the Provincial Interconnected System is three times the wholesale price of the energy sold to the provinces in the National Interconnected System.

On the basis of the profit and loss accounts included in the balance sheets of the Cooperative de Electricidad de Montecarlo Ltda., an approximate calculation of the distribution and commercialization costs has been made. The rural service comprises two main categories of users: residential and industrial. In the case of the Montecarlo Cooperative, the industrial users have an important relative participation which defines a higher power density and a larger proportion of three-phase against single-phase lines; they consequently have a differential participation in the costs. In the rest of the province, the relative participation of industrial rural users varies and significantly decreases in the case of the potential users of the non-serviced areas which are the object of this research.

In order to use indicators which permit extrapolation results from the areas in operation to the non-serviced areas, it was deemed necessary to adapt rural service costs between residential and industrial users. The distribution and commercialization cost average for the 1985–1986 period was US$0.1778/KWh. Phase I of the RETAIN Project included an analysis of the distribution and commercialization costs for the Oberá Cooperative, the main company rendering the service in the rural area which was selected for the case study. The analysis was performed on the basis of more aggregated information since this cooperative does not keep a separate account for the rural service. The Oberá Cooperative possesses user structure (residential/industrial), user density and power density indicators similar to those of Montecarlo. The values based on the 1985 financial year yielded a mean cost of US$0.1703/KWh (adjusting the rate of exchange to the Theoretical Balance Per Value used in this study).

Payment Plans for Users

The method used for developing the electrification plans has burdened the users with the payment of the total investments made on the rural system, under variable financing conditions. Contrary to what happens with urban users, the magnitude of the investments (on distribution) per user in the rural area is very high and consequently places the rural user in a clearly disadvantageous situation as compared to the former. The payment plans used to date only allow the higher income settlers to enter the system, leaving a significant number of inhabitants without service in the electrified area. Readjustment policies and interest rates have resulted in instalment variations greater than farming prices and consequently have forced rural users to make a greater economic effort than expected. In many cases, they too stopped paying.

Tariffs and Subsidies

In Misiones there exists a uniform tariff schedule for the whole province which is fixed and periodically updated by the sector's political authority (Ministry of Public Works and Utilities). The tariff applied to low consumption residential users is aimed at the social situation of these very low income groups. Consequently, the income proceeding from the sales to this category of users is quite different from the costs they incur in the system.

There are direct and indirect subsidies which make up for the gap between the income from the tariffs and the actual costs arising from the service operation. A first level of subsidies occurs in the transactions between EMSA and the cooperative societies. This is to ensure that the mean income from the sales of energy (at the effective tariffs) to all categories of cooperative users, after deducting the energy purchases from EMSA, meet the mean distribution and commercialization costs which the cooperative societies must incur for correctly rendering the service. This subsidy is implemented through the tariff energy sales to distributors (cooperative societies) in the Provincial Interconnected System, which is significantly lower than EMSA's generation and transmission costs. A second level of subsidies occurs within the cooperative societies through the transfer of income from urban users to the rural ones and from the remaining user categories (medium and high consumption residential, industrial, commercial) to the low-income residential ones. Table 9.5 summarizes the subsidies.

Table 9.5 Provincial System Subsidies to Rural Residents

Item	Heading	US$/KWh
1	Generation and transmission mean cost	0.100
2	Mean tariff to cooperative societies (Ref. Montecarlo 1986)	0.028
3	Province's subsidy to cooperative societies	0.072
4	Distribution and commercialization mean cost appropriated by residential rural user (1985/1986)	0.178
5	Cooperative society's mean income, residential rural user category (1985/1986)	0.052
6	Cooperative society's net income, residential rural user category (item 5–item 12)	0.024
7	Cross subsidy in commercialization and distribution (Cooperative Soc.) (item 4–item 16)	0.154
8	Residential rural user total mean cost (item 1 + item 14)	0.278
9	Total subsidy per KWh consumed by a residential rural user (item 3 + item 7)	0.226
10	Residential rural user mean annual consumption (Ref. Montecarlo Cooperative Soc. 1985/1986)	1168 KWh/yr
11	Total annual subsidy per residential rural user	264US$

10

Hydroelectric Micro Power Plants

A significant development of Hydroelectrical Micro Power Plants as an alternative technology for the supply of electrical energy in the rural areas has been attained in Misiones. This development, performed in little more than a decade, occurred in two stages. The pilot technological development stage was based on the performance of single-family projects with limited government support. Between 1976 and 1984, there were seventeen projects, two which were of a collective nature to be modified and improved later. The demonstration unit development stage, with greater government support, was where collective projects are performed. At this stage, the technological scale change is adjusted and the first institutional and organizational aspects of this electricity supply method are approached.

In the second stage, performed between 1984 and 1988, five new collective projects were carried out and the two existing ones modified. Government support allowed the creation of the Hydroelectrical Micro Power Plan Development Regional Center, and user partnerships were organized for building the micro power plants and for operating the service.

Resources

Both the family pilot unit development stage and the collective demonstration unit have been characterized by the participation of several institutions which contributed human, material or financial resources to HMPP development. In Table 10.1 the resource origin has been traced according to each participant in the programme, and the financial value thereof has been quoted since the beginning of activities in 1976 to December 1987.

Table 10.1 Institutions and Resources Assisting in HMPP Development

Origin	Period	Type of Resource			Valuation
		Human	Material	Financial	US$
Provincial Government					
Electricity Board	1977/79	X	X	X	10,500
APDS	1979		X		2,700
Planning Secretariat	1980			X	600
Hydric Resource Board	1983/84	X	X	X	86,000
Municipalities	1984/87		X		20,000*
HRB and EDEMSE	1984/87	X	X	X	493,000
Provincial Road Engineering Board	1984/87	X	X		6,600*
Provincial Government Subtotal					619,400
Misiones University Engineering School (IDIP)	1978/84	X			7,800
IDIP-CREDMHI	1984/87	X	X		58,500
Humanism and Social Science School	1984/87	X			3,500
University Subtotal					69,800
National Secretariat of Science and Technology	1982/93			X	7,600
	1985			X	24,700
NSST Subtotal					32,300
National Energy Secret. CREDMHI	1985/87			X	932,300
Energy Secret. Subtotal					932,300
Private Contributions					
Bldg. Company (Ing. Coll)	1979		X		2,700
Equipment Supply Cost (Risko-Bicovich-Gaillou)	1974/84	X	X		5,000
FUD-IDDE-IDRC	1985/87	X		X	64,400
Private Contr. Subtotal					76,100
Users	1976/84	X	X		30,000
	1984/87	X	X		66,500*
User Subtotal					96,500

*Estimated values

Pilot Projects

This development stage centered on the experimentation of technological alternatives and was based on the initiative of researchers and users' personal interest. Institutional support was discontinuous, no centralized organization was maintained and the legal background provided was designed to promote the private interest in the application of this technology. By means of Decree 12.11/80 the provincial government establishes a special credit line for private investors who wish to build HMPPs on their property.

Total investment in the pilot projects was US$50,000. Mean cost per installed project was US$1,815/KW. Mean cost per user was US$1,666/KW.

Demonstration Units

In this stage progress was made in the search for construction methods which might allow a cost reduction and an increase in the utilization of local materials. Successful experiments were made with earth dams without any special compaction, barrages having concrete buttresses with wooden shutters and the so-called enrockment barrages consisting of concrete structures with large fragments of basaltic rocks.

Through a cooperation agreement between the CREDMHI and the Hydraulics Laboratory of La Plata National University, tests were carried out on Banki model turbines and the vane type injector which was used in Misiones. These tests made it possible to optimize the machine's geometric parameters, raising its yield from 60 to 73% in the last model tested with injection radial gate.

The demonstration units showed new technical requirements related to the regulation of the machines which, in this case, had to serve small systems having more complex operations. On one hand, the adjustment of the regulation, protection and remote control systems was a new advance in the technology development; on the other, the trouble caused by outages aroused the users' distrust and required great efforts on the part of the team responsible for maintenance. (Misiones, having a subtropical climate, undergoes periodic strong electric storms which in the HMPP caused damages in the regulation and control circuits.) New digital prototypes developed in this stage take the frequency reference at the rotation axis; consequently, they are independent from the micro power plant electrical system and operate very reliably.

Legal, Institutional and Organizational Aspects

From the institutional and organizational point of view, the activities of the demonstration unit showed a higher degree of coordination. The main institutions were Misiones Ministry of Public Works and Utilities (channelled, in a first stage, through the Hydric Resource and Electrical Construction Department), Misiones National University School of Engineering and Oberá University Foundation, all of whom started the so-called Hydroelectrical Microdevelopment Programme in March, 1984.

The stated objective of this programme was the electrical energy supply to low income rural inhabitants settled in areas not being supplied by the present electrical system. From the organizational point of view, Misiones HMPP Programme has been conducted by a work team of professionals and assistants from EDEMSE and the School of Engineering. (Later on, the professionals assigned to the programme became part of the company. To this end, the Non-Conventional Energy Office was created within EDEMSE's Planning Project and Works Management.) The main responsibility for resource research, project performance and the management and inspection of civil and hydraulic works and transmission lines fell to EDEMSE. The School of Engineering and the University Foundation were responsible for the technical and quality assurance specifications, the acceptance and assembly of the electromechanical equipment, the technical assistance and training of the partnerships and the subsequent maintenance of the facilities. The Ministry, through EDEMSE, is responsible, in a first stage, for financing the projects as public works, within the legal system in force.

CREDMHI

Later on, the National Energy Secretariat actively joined the programme, contributing financial assistance for the technological development, propagation and execution of demonstration units. It does this in accordance with the guidelines of the National New Energy Source Programme approved by Decree 22.47 of November 22, 1985, by promoting the creation of a center specializing in the development of HMPP by means of Agreement S.E. 1474, dated December 26, 1985, entered into by the Secretariat, Misiones Province and Misiones National University.

Against the background of this cooperation agreement with the National Energy Secretariat, Misiones Province and Misiones National University constitute, by virtue of the Agreement made by them and executed on the 28th February, 1986, the Hydroelectrical Micro Power Plant Development Regional Center (CREDMHI), whose seat is the School of Engineering in the city of Oberá.

The CREDMHI institutional structure includes a Coordinating Committee made up of two members, a regular one and an associated one, for each of the parties subscribing to Agreement S.E. 1474. The Coordinating Committee is the highest center authority and its duty is to evaluate the requirements and propose annually to the Energy Secretariat the work programmes and the corresponding budget. It holds meetings every six (6) months and prepares an annual detailed report. An executive manager is appointed by the Province's governor upon the proposal of the Ministry of Public Works and Utilities. An executive co-manager is appointed by Misiones National University, upon the proposal of the School of Engineering. Both managers remain in office for two years. Personnel are from the organizations constituting the Center and fellowship beneficiaries working on research and development projects.

CREDMHI's purpose is not limited to supporting the HMPP Programme in Misiones. Its field of activity covers all national territory; it has become a highly specialized center and acts as an advisory organization for the Energy Secretariat and all the provinces.

User Partnerships

The execution of the works was assigned to partnerships constituted by the beneficiaries thereof, according to the provisions of Provincial Act No. 885 passed in 1977. The execution partnerships are governed by a collegiate body of five members. The chairman is appointed by the Ministry of Public Works and Utilities; the secretary, treasurer and two other members are elected by the beneficiaries of the projects in a general meeting. Once their authorities have been appointed, the execution partnerships obtain a legal status through their registration with the Provincial Bureau, which allows them to administer the funds transferred to them.

The partnership method had already been successfully tried in architectural works and its application allowed the future users' contributions to be channelled through labour, machines, tools and other material which resulted in a significant reduction in the cost of works (as much as 35% of the official budget; see Mercanti, 1987).

The experience of users' participation in the works execution led the authorities to extend this principle to the HMPP exploitation and management activities by appointing management partnerships having a similar structure to the execution ones. However, these were not comprised in Act 885 and consequently had no legal background to support them. Lack of both regulations and a service authority higher than the management partnership rendered the monthly instalment collection difficult. This resulted in a low level of user participation in cleaning and maintenance activities and a significant lack of participation in the meetings intended to solve common problems. To face this situation a set of Partnership Regulations was prepared and enforced for the Operation and Management of Isolated Hydroelectrical Micro and Mini Power Plant Electrical Service.

Other normative deficiencies have been detected which restrict the provincial authority. The capacity in which the exploitation of the works is granted to partnerships has not been regulated; consequently, the legal requirements in force for the granting of public utilities, hydric resource exploitation or public works, as applicable have not been complied with. The nature of the granting not being determined, no granting agreements with the organized users may be executed and there is no contractual background determining the duties, rights, penalties and terms applicable to the parties. No negotiations have been made, either, for declaring the public utilization of the land affected by the works and the HMPP reservoir, and the respective rights of way and of passage of electrical lines. The lack of an appropriate legal background has led to an uncertain situation as regards eventual occupational accidents, labour claims or damage to third parties which may take place during HMPP operation.

Results and Economic Indicators

The references and indicators of the works performed in this stage are shown in Table 10.2. If in the table the additional costs for expanding the capacity of the HMPP up to their nominal value (future capacity) and the incorporation of new users up to the maximum number permitted (potential number of users) are considered, the mean unit costs for an optimum utilization of the demonstration units in operation are obtained.

Table 10.2 Indicators of the Demonstration Units

Project	Number of Users		Installed Capacity (KW)		Amount of the works (US$)		Present Cost per User		Present Cost per Inst. KW (US$)
	In	Po	Pr	Fu	w/lin	wo/lin	US$/ Us	w/lin	wo/lin
Dorado	11	11	8	10	50,228	48,978	4,567	6,278	6,122
Persiguero	10	10	7.5	10	54,610	44,203	5,460	7,282	5,894
Pereyra	25	30	28	28	90,940	75,571	3,498	3,247	2,699
Carlitos	20	20	15	15	78,474	49,196	3,877	5,231	3,280
Tarumá	40	90	40	80	134,220	98,195	3,355	3,355	2,425
Central	15	25	25	25	99,154	75,174	6,610	3,966	3,007
Pesado	15	20	20	20	45,903	31,252	3,060	3,531	2,404
Total Projects	137	206	143.5	188	562,529	422,569	4,106	3,920	2,945
Total New Projects	116	185	128	168	457,691	329,388	3,946	3,576	2,573

Ref.:

Number of Users:	In: Initial	Po: Potential
Inst. Capacity:	Pr: Present	Fu: Future

Table 10.3 HMPP Investment Costs in Misiones (US$)

	New Projects	All Projects	RETAIN Phase 1
Mean power module (KW)	33.6	26.8	19.4
Cost per user	2,600	2,860	2,681
Cost per installed KW without lin.	2,060	2,860	2,035
Cost per installed KW with lin.	2,724	3,142	3,215

In the light of these results it can be affirmed that the HMPP development programme in Misiones has attained a sufficient technical maturity degree and has proved the economic convenience of using this supply alternative for meeting the electricity requirements of the rural inhabitants. The institutional, organizational and financial aspects will, no doubt, be the greatest restrictions in formulating the Normative Plan for the mass promotion stage of this technology.

The resources allocated to the programme have had two different destinations: direct costs and development costs. The direct costs are those resources directly used by the project and building stages up to operation. Development costs include a series of investments and expenses: Research and technological development promotion campaign, technical assistance for developing the suppliers of equipment and components which were not available in the market, technical follow-up to final adjustment (including maintenance activities); analysis and follow-up of social, economic, institutional and organizational matters associated with the introduction of the new source in the rural environment. The development costs were calculated as per the difference between the total allotted funds and the direct costs. These are shown in Table 10.4

Table 10.4 HMPP Development Costs in Misiones (US$)

Stage	Period	Total Funds	Direct Work Costs	Development Costs
Pilot Projects	1976/84	152,900	50,000	102,900
Demonstration Units	1984/87	1,637,500	562,529	1,110,971

The absence of specific accounting in the programme does not permit exact allotments corresponding to the different destinations of development costs. However, according to participants in the programme, percentage estimations can be made as follows:

- Engineering development (surveys and research) 40
- Development of socio-economic aspects (survey and research) 10
- Technical assistance to micro power plants 10
- Equipment (vehicles, communications, workshops) 20
- Operation and training overhead 15
- Promotion expenses (meetings, publications) 5

11

Determination of the Market Size

In defining a market size concept, the first approach determines the magnitude of the HMPP building and operation programme which will take place in Misiones Province when this supply method is incorporated into the option menu required for solving the unsatisfied electrical energy needs of its rural population. This approach defines the first number of potential HMPPs on the basis of participation as a minimum economic cost solution in the whole province supply planning. This first quantification shall be deemed 'maximum', whereas a second quantification, deemed 'minimum', shall refer to that portion of the former which is located in the areas which are farthest from the networks and where there is a larger institutional consensus (see Chapter 12) for the incorporation of the HMPP as the basis for the electricity supply planning. These 'maximum' and 'minimum' projections shall constitute the basis for developing and giving dimension to all the aspects making up the Normative Plan for the HMPP expansion in Misiones.

Some aspects of the Normative Plan, such as technical assistance and supplier development activities, will be influenced by extraprovincial demands. The available information on the present and potential HMPP development programmes in other provinces and countries of the area will permit the quantification of the extraprovincial demands for work and equipment supply and the estimation of the potential participation of the local companies and institutions in the provision of supplies and the associated technical assistance.

Provincial Demand

Argentina's RETAIN Project was devoted to the development of a methodology for evaluating electricity supply alternatives in depressed rural areas. The methodology assumed a supply planning based on an itemized analysis of the rural inhabitant energy requirements and of the energy resources and technological alternatives available in the region. The evaluation stage includes all the possible supply alternatives and the minimum economic cost solution which may become a combination of said alternatives. A case study for the methodology application was made in the region comprising Oberá and Cainguás (see Chapters 3–5).

Over 400 HMPPs were identified; 90 of them remained as part of the minimum cost supply solution for the region. The outcome of this detailed study and the rich technical and economical information available made it possible to extend the evaluation results obtained in the two departments to the whole of the province. The extension of the results obtained for Oberá and Cainguás departments was based on an expeditious method which correlates HMPP penetration with indicators which are typical of the area studied. As an indicator of the HMPP penetration, the following ratio was adopted:

$$Pi = \frac{\text{Number of Users Supplied by HMPP}}{\text{Number of Total Area Users}}$$

The following indicators were analyzed to explain the results obtained in Oberá and Cainguás: Theoretical Gross Lineal Potential (KW/km), TGHP Density (KW/sq.km.), Quantity and Mean Power of Identified Locations, Quantity and Mean Power of the Locations Used in the Population Density Model. The analysis of the correlation between these indicators and the Pi led to several conclusions.

Although the Lineal Potential and TGHP offer an idea of the potential which is technically usable on the microgeneration scale, they do not reveal how much of that is economically profitable and therefore do not directly correlate with the Pi. The mean area population density is high and its variations do not show a relationship with the Pi. It was noticed that the basin quality indicators, when combined with the mean power of the locations used, allow a very good explanation of the HMPP penetration results obtained in Oberá and Cainguás. The mean power calculation of the sites which might be located in the rest of the province would require a planning and evaluation study as detailed as the one carried out in Phase 1 for Oberá and Cainguás. An effort of such magnitude exceeds the scope of the present survey. Instead, using basic maps, a quanti-qualitative indicator was constructed based on the relationship between the area having highly erodible soils (identified in the maps as steep grade soils under code 6–B) and the total basin area, as modified by the qualitative appraisal of the level line piling degree shown in the maps for the same basin and whose patterns were constructed on the basis of the Oberá and Cainguás basin behaviour. This indicator is called the Gradient Index and is divided into three levels—low, medium and high—corresponding to low, medium and high usable mean power areas.

With the TGHP and Gradient Index as basic indicators that explain the HMPP penetration, and starting from the available information on the 28 sub-basins in which Oberá and Cainguás departments were divided, a correlation matrix was defined which allows the calculation of the estimated Pi value for the rest of the province to be made. These varied from a low of 0.05 to a high of 0.80 and are considered conservative.

Once the level line piling patterns defined the Gradient Index and Penetration Matrix, the results were extended to the rest of the province. The hydraulic interest departments were pre-selected on the basis of their hydrographical and topographical characteristics. The departments corresponding to the so-called 'field' of little relief were eliminated. The 'mountainous' areas (13 departments in all, covering 88% of the province) were selected based on hydraulic interest. These were sub-divided into 140 sub-basins based on mean values different from their basic indicators (depending on their being high, medium or low basin areas) and maximum size which would allow information regarding potential users. In each sub-basin the TGHP and its density and the percentage of 6–B soils were calculated.

The hydraulic interest departments were also sub-divided into census factions for information on households having no electrical services and the estimated number of potential users in the rural areas located away from the networks. By means of cartographic overlapping, each faction was given a weighted Pi value which takes into account the Pi values of the sub-basins making up the faction. Starting from the faction figures, department subtotals were calculated which, added to the already known information on Oberá and Cainguás, permitted the estimated maximum total number of users for HMPP expansion based on the minimum economical cost solution. Three mean power modules were established which are shown in Table 11.1. The results obtained for the rest of the province were redistributed into these three modules, assuming the same relative participation in the remaining departments as in Oberá and Cainguás.

Table 11.1 HMPP Mean Power Modules

Range (KW)	Quantity	Mean Module (KW)	Relative Participation	Average No. of Users
Up to 10	18	7.5	0.20	7
10 to 25	50	15	0.56	14
Over 25	22	40	0.24	57.5

The estimated maximum values, as distributed per department, are shown in Table 11.2. The value estimated as minimum corresponds to the HMPP having a module greater than 10 KW in the north-eastern departments of the province where the basic infrastructure for the centralized system expansion is very deficient. This area includes Cainguás, Guarani, 25 de Mayo, San Pedro, Belgrano and Iguazu where there exists great institutional consensus for the utilization of the New Energy Sources as supply options for completing the limited supply which the Provincial Interconnected System may provide over a medium term. In this minimum hypothesis, only the greater mean module HMPP are considered so as to reduce costs and simplify the organization and technical assistance aspects of the model.

On the provincial scale and considering the outcome of the financial and macro-economic analysis of Project I, the market size and its effects are shown in Table 11.3.

National Demand

Up to 1985, when the National Energy Secretariat started to give greater impulse to the promotion of the New Energy Sources, only Misiones and Neuquén had started official

HMPP development programmes. The basic indicators of Argentina's HMPP inventory is shown in Table 11.3 The Energy Secretariat's financial support for the development of demonstration units aroused greater interest in some provinces having sufficient hydric resources to start experimenting on the application of this technology.

At the demonstration unit level but without having HMPP projection into their provincial markets, Salta, Sante Fe, Jujuy, Mendoza, San Juan and Santa Cruz were already working in 1988. Among them, the experiences carried out in Mendoza and Salta, with the assistance of Mendoza National University School of Engineering, seem to have a larger development potential. In the case of Mendoza, which has an extensive network of irrigation channels, the aim is to incorporate in them the electrical energy production by employing gate-turbines having a very low cost per installed KW. Salta's programme is similar to the Misiones one since its purpose is to supply electrical energy to small isolated communities with power modules on microgeneration scale.

Table 11.2 Market Size: Maximum Provincial Demand

Department	Mean Pi	Total No. of Users	No. of HMPP Users	No. of HMPP	No. of HMPP according to power		
					7.5 KW	15 KW	40 KW
Oberá	0.34	2,845	975	42	8	24	10
Cainguás	0.38	2,949	1,116	48	10	26	12
Eldorado	0.25	2,210	544	23	5	13	5
Guarani	0.53	2,636	1,394	60	12	34	14
Iguazu	0.17	1,195	208	9	2	5	2
L.N. Alem	0.22	2,001	448	19	4	11	4
L.G.S. Martin	0.22	1,364	295	13	3	7	3
G.M. Belgrano	0.47	1,190	565	24	5	13	6
Montecarlo	0.43	944	403	17	3	10	4
San Ignacio	0.08	2,312	195	0	2	4	2
San Javier	0.16	975	154	7	1	4	2
San Pedro	0.67	1,051	706	30	6	17	7
25 de Mayo	0.36	1,978	705	30	6	17	7

Table 11.3 Maximum and Minimum Provincial Requirements

	Maximum Hypothesis	Minimum Hypothesis
Market Size		
Total HMPP	330	160
7.5 KW mean module HMPP	67	
15 KW mean module HMPP	185	112
40 KW mean module HMPP	78	48
Required Investments (US$)		
Total	22,000,000	12,500,000
Civil works	12,150,000	6,900,000
Equipment	3,150,000	1,800,000
Network	6,700,000	3,800,000

Table 11.4 Argentina's HMPP Inventory

Province	Works in Operation	Installed Capacity (KW)	Works Under Study
Catmarca	3	220	4
San Juan	-	-	1
Neuquén	6	395	11
Mendoza	2	17.5	1
Tucumán	-	-	2
Entre Rios	-	-	1
Santa Cruz	-	-	1
Chubut	-	-	2
Jujuy	2	35	3
Salta	3	130	5
Santa Fe	-	-	2
Corrientes	3	60	14

A more advanced level is found in Corrientes Province which has started to incorporate electrical energy production in its rice field irrigation reservoirs. In this case, besides the three units which were equipped with Banki turbines in 1988, there are fourteen other users identified. It is estimated that over a medium term 50 users may be added in a farming production improvement programme having IDB financial assistance. The main objective is to expand the rice field irrigation infrastructure. Over the long term, it is estimated that 900 irrigation reservoirs may be built with the possibility of incorporating the electrical energy production as a complement.

Regional Demand

The Republic of Paraguay is currently working on the development of demonstration units at the Nuestra Señora de la Asuncion Catholic University, with assistance from Germany. To date there is no official programme for the promotion of HMPP on a larger scale. In the Republic of Bolivia, ten HMPPs have been planned. Salta may send them technical assistance and equipment from Argentina. A larger regional projection can be seen in the case of Rio Grande do Sul where the State Mining and Energy Department, together with the electricity company and the area universities, are planning a programme of HMPP to be used parallel to their very extensive rural electrical service. The range of power modules to be used goes from 0 to 500 KW, and the estimated number of power plants is 600.

12

The Normative Plan

Scope and Limitations

The diagnosis of the rural electrification process situation in Misiones showed the magnitude of the unsatisfied electric energy requirements of the rural inhabitants. The market research showed the potential HMPP participation in the technical-economical solution for the supply. These preliminary studies made evident the limitations which are common to the penetration of any energy technology in the rural medium, as summarized by the low levels of investment on the electrification plans and by the lack of a planned background for the recovery and development of the rural sector in which such plans may be inserted. With regard to the evolution of technologies used in the rural electrification process in Misiones, Table 12.1 shows the most significant comparative data which explain the different relative penetration degrees.

The normative plan had to be based on the technical-economical suitability criteria and the set of comparative limitations and advantages. The feasibility plan requires agreements between the institutions of the sector making it possible to find a complementing formula.

Rural electrification development in Misiones has been technologically dominated by the extension of networks from the Interconnected Provincial System. In former years, the low HMPP technological development aroused in certain officials a limited interest in large-scale potential utilization. Many managerial officers still consider this alternative an academic exercise for training engineering students. The Light and Power Workers' Union has not lent its decisive support to the HMPP as a complement to the rural electricity supply either. Reasons are institutional. The self-managed nature of the small systems supplied by the HMPP keeps the Union from exercising its natural jurisdiction on the operation and maintenance personnel involved in the service. Furthermore, the decentralized organization typical of the HMPP is opposed to the greater centralization criteria traditionally defended by the Union in its proposals for the Regulation of the Electricity Public Service.

Table 12.1 Comparative Synthesis of Alternative Technologies

Subject	Networks	HMPP
Technical development	Complete, highly improved and receiving innovation	Complete during test and improvement period
Rigidity in application of Technology	Linked to development of transmission and subtransmission lines	Linked to existence of water resource
Supplier development	Complete, diversified, regards material and assembly supply	Partial, limited in turbine and controller supply; complete, diversified for other components
Manufacturing standards and quality	For every component; laboratory certified material and equipment	Being prepared for turbines and controllers; for generators, same as networks
Time of use in Misiones	30 years	10 years
Main execution unit	Public electricity utilities	Research institutes
Service reliability	Greater	Lower
Investment costs*	US$ 2,400/User	US$ 2,700/User
O&M costs	US$ 325/User per year	US$ 30/User per year
Degree of participation required from users	Low	High
Subsidies to investment costs	None	Total
Level of technical assistance during service exploitation	Very good; highly qualified, well-equipped personnel	Good; based on engineering students; delays in emergency assistance
Legal background	Public utility with determined legal background; large number of specific norms	No specific norms
Institutional development	Consolidated; well-defined roles for political power and service performers	Being developed; undefined roles; low degree of coordination

* Corresponding to mean values. For a more detailed analysis of the investment costs, refer to Chapters 9 and 10; the available power in the network supply is larger than in the HMPP case since they correspond to users having different requirements.

The magnitude and seriousness of the supply problem were debated and analyzed at a work meeting held with officers of EMSA, EDEMSE, the cooperative societies and representatives of the energy policy secretariat of the Union. This meeting and the publication of the evaluation study carried out in RETAIN Phase I helped to reduce the opposition to the use of this new technology.

General proposals and consent for the expansion plan were developed during this consultation process. Since the province's north-eastern area has the lowest electrification degree and the most precarious electrical infrastructure conditions for developing the centralized system, it was defined as an area of interest. The final HMPP locations should be made compatible with the present rural network extension plans in order to avoid overlapping and competition between both supply models. Selection of those HMPP having motivation and potential users with contributive capacity implies carrying out a prior socio-economical evaluation. A legal and normative background should maintain the present self-producer system but guaranteeing, through strong government regulation, every neighbour's right to electrical energy in accordance with the power available in the HMPP. This should additionally provide a non-conflicting setting for labour relations within the user associations. Since the HMPP electricity supply planning is a transition infrastructure, the norms shall entrust the sector's authorities with the HMPP destination once the networks have been extended up to the small systems served thereby. The HMPP applications should diversify to include the supply of water for human consumption and other purposes bearing social and economic development for the beneficiary community. The scarce financial resources available for rural electrification should not be appropriated by EMSA networks. The partnership institution presently adopted by users should have the legal capacity to assume public liabilities. HMPP maintenance and technical assistance activities should transfer from the research institutes to the electrical service performers and private enterprises. Institute activity should focus on technical and socio-economic follow-up, innovative development, user training and specialized maintenance tasks for the HMPP electromechanical equipment.

Material Goals and Temporal Scope

The outcome of the consultation meetings has shown the advantage of establishing the material goals of the Normative Plan within the Minimum Hypothesis in the market research (Chapter 11). Material goals sought to be attained by the Plan development are separated by departments in Table 12.2.

Table 12.2 Material Goals of the Normative Plan

Department	15 KW Mean Module HMPP	40 KW Mean Module HMPP	No. of HMPP Users	No. of Small Systems
Cainguás	26	12	1,116	38
Guarani	34	14	1,394	48
Iguazu	5	2	208	7
G. Belgrano	13	6	565	19
San Pedro	17	7	706	24
25 de Mayo	17	7	705	24
Total	112	48	4,696	160

In order to attain these goals, three plan phases have been foreseen. Phase I—Pre-investment includes all the basic activities related to the organization of the execution unit and to the improvement of the legal plan and normative background as well as those related to planning, economic and social evaluation and finance negotiation. Phase II—Investment comprises all the bidding, hiring, follow-up and acceptance of the works and supplies making up each small system and its starting-up and industrial testing. It also comprises the formation of the user associations of the HMPP to be built and the drawing up and signing of the assignment documents granting the exploitation of the resource and the works and facilities, as well as the technical, administrative and management training of users. Phase III—Exploitation comprises government assistance, regulation and control activities during the exploitation of works, user participation in the operation and maintenance thereof and specialized technical assistance by third parties.

It was deemed convenient to break down Phase II into a five-year period. This distributes the investment and management effort, facilitates the necessary adjustments and optimizes the utilization of the human resources allotted to the Plan.

Legal Background

In this aspect of the Plan, the analysis was directed toward the definition of a normative basis for the relationship between the rural inhabitants who benefit from the works and the provincial government as a promoter and executor of the supply programme and the owner of the water resources located within its jurisdiction. In order to facilitate the legal background for the plan, the relevant set of rules should be based on the laws in force. In this way, there is no need to create new legal instruments such as acts or decrees which are difficult to carry out.

The main frame of the legal analysis is based on Chapter 3 of the Misiones Constitution, 'Energy and Public Services', from which there are two main aspects. The first is that the province has the absolute, imprescriptible and inalienable ownership of the natural energy sources located in the territory. Second, it allows private participation in the electrical service exploitation in places or centers of lesser importance, in conformity with the specific legislation, by means of concessions granted to small companies and individuals. As for the rest, the legal background for the execution, assignment and redemption of the works is based on the Misiones Water Act (No. 18.38/83), complemented, as regards the concession aspects, by the Energy Act (No. 3.59/67). The user organization is, in turn, framed in accordance with the association and corporation institutions foreseen by the Argentine Civil Code.

Two other aspects were debated at the work meetings to define the basic legal background on which the HMPP Expansion Plan is to develop. The first concern was whether this particular small user association, organized under a suitable corporate form with the purpose of generating electrical energy for its own consumption, should be deemed subject to the rules governing the public electricity service or whether they should be considered self-producers. The second aspect, specially emphasized by the provincial authorities was whether the works should concentrate exclusively on their electrical production purpose or whether they should be more amply considered as development works having a multiple purpose.

Public Service and Self-producers

The public service institution ruled by Provincial Act No. 3.59 ensures a high degree of government intervention in the building and exploitation of the works which has the advantage of more effective financing and execution. It also offers a stronger guarantee of respect for HMPP neighbour rights to electrical energy during exploitation. On the other hand, this implies a more complex procedure combining public service concessions (Sections 16 and 17 of Act No. 22.18/85 by virtue of which EDEMSE was created) and concessions for the utilization of hydraulic energy sources (Sections 76–80 of Act 18.38/83).

In view of these limitations, it was suggested that the small systems be fitted into a self-production scheme. This solves the concession normative problems which are thus limited to the hydroelectrical source exploitation. It permits full application of the self-management principle according to a management plan which is more flexible and suitable for the socio-cultural characteristics of the potential users. The legalities are restricted, in this case, to the provisions of Act 18.38 within a free system which reduces the previous concession granting procedure, makes it possible to designate works to other purposes and facilitates self-management which is less complex for the provincial government in the roles it must perform during exploitation and for the user association.

Act 18.38, in turn, preserves active government participation in private concessions. During the investment phase, the government channels financial assistance required by the scarce user saving capacity. During exploitation, there is government supervision of fair and equitable distribution of the profits arising from HMPP utilization.

Electricity Production Purpose and Multiple Purposes

The self-production approach supported by Act 18.38/83 makes it possible to classify the HMPP as socio-economic promotion and the development works as having multiple purposes. This facilitates the appropriation of public funds for the execution of the provincial authorities concerned with solving the water supply together with the electric energy supply and at the same time improves the rural sector production outline.

The Water Act (18.38/83) contains a sufficient number of provisions for handling an HMPP expansion plan. The activities regulated by the Water Act and, particularly, those which derive from an HMPP Plan must fall under the jurisdiction of the Ministry of Public Works and Services (MOSP). The Expansion Plan works are deemed to be Socio-economic Promotion and Development Works (Section 108) having multiple purposes as per the following hierarchy of applications: Electric energy, household water consumption, irrigation (agricultural application), industrial, fish-breeding, recreation. The provincial government shall resolve the execution of the HMPP (Section 108 of the Water Act) and grant the concession of the special utilization of Waters and Works (Section 33) to the users organized under a suitable corporate body (Section 48). The MOSP shall regulate the concession procedure. The users' contribution to the partial financing of works will be made through improvement of the contribution system (Section 109).

The concession agreement shall contain an express indication of the public property involved in the concession—reservoir area, sealing, intake and conduction systems, engine room, hydromechanical and electromechanical equipment and transmission networks up to the user's connection. It should give the technical specifications for works, installations and equipment and the topographical datum of the ground taken. The extent of the rights of way for the passage of water and electric conduits shall likewise be indicated. It should contemplate active exercise of MOSP police power for control and surveillance of the applications and purposes for which the concession was granted, with power for arbitration in user association internal affairs, and for imposing sanctions and declaring the expiration or annulment of the concession when the users' association fails to fulfil its obligations or uses the water or the works for other applications than those which caused the concession to be granted. MOSP shall approve the user association internal regulations in accordance with the criteria agreed upon in each association, within the basic regulations which are common to all concession agreements. It shall ensure all rural inhabitants the right to electric energy in accordance with energy availability and ensure the rational utilization of the energy and power available in the small system. To that end, the power levels to be used in the connections in accordance with the different user categories shall be indicated. A minimum power category, suitable for meeting a basic electricity requirement level of the rural inhabitant, shall be contemplated for those inhabitants having no payment ability. It shall establish the concession term for a recommended ten years (renewable) and preserve the rationality and efficiency in the development of the Provincial Electrical System, anticipating the expiration of the concession in respect of the electrical application of the works and the source, when the time comes for the networks extended from the Provincial Interconnected Systems to be in a position to service the area covered by the HMPP. Then the MOSP will decide on the destination of the generation and electricity distribution facilities (proposed alternatives are the parallel interconnected operation with the centralized system networks or its isolated utilization for either industrial or production purposes of the beneficiary community). Clauses regulating expiration or the total or partial annulment of the concession shall provide the conditions and methods of compensation for material and human and financial resources contributed by the rural inhabitants for the building of works.

Present Partnership Institution

The partnership is not considered in the Argentine legal system as a conventional person; consequently, in accordance with the Water Act, it cannot be given a concession for the utilization of waters and works. The partnership institution has been provided by the Public

Works Act for the purpose of carrying out a certain public work, its duration being restricted to the term required for completely finishing the works involved. It was then improperly used for the exploitation phase of the first HMPP demonstration units in Misiones.

It has not been foreseen as an 'associative entity' having legal capacity which is an essential requirement for differentiating a conventional person distinct from its individual components and having regulated agents charged with specific duties. Hence there is a need to look among the institutions contemplated in the different laws and codes for one which may adjust to the requirements of the abovementioned entities which have multiple associations not only with their partners but also with government and whose decisions might even have unfavourable effects on third parties.

Possible Alternative Corporate Institutions

One of the legal institutions which has enabled several towns to have an electric energy supply is the cooperative corporate form. These act mainly as distribution organizations and are given a hierarchical position in the provincial constitution. One advantage of the cooperative society is that, once it has been incorporated, the admission of new members requires no amendment to the by-laws or articles of incorporation. One disadvantage is the necessary intervention of national jurisdiction through the Cooperative Action Secretariat to authorize operation. Also, other requirements supervised by the national government have to be met; these usually include gathering personal data on Board members and involve a significant delay in the approval of by-laws. A second peculiar aspect of the cooperative society is its business purpose; consequently, those working for it need to be included in the collective bargaining agreements. This implies leaving aside the proposed self-management concept and may mean an additional operating cost which not all of the undertakings are in a position to bear.

For those partnerships having their maximum power allotted from the start-up and which will not, consequently, modify their number of users for a long period of time, a simple institution to be quickly established might be the Civil Society. This is incorporated by a non-officially recorded document or by notarial deed (Sections 1648 and 1662 of the Civil Code). The advantage is the autonomy it enjoys for amending its incorporation papers without government intervention or authorization. It may adopt various forms according to the provisions of Section 1662.

The third and most suitable institution is the Civil Association provided by Section 33 of the Civil Code. This deals with private corporations and refers, in the first subparagraph, to those associations whose purpose is public welfare, which have their own capital and are capable, according to their by-laws, of acquiring property, which do not live exclusively on government allowances and obtain a permit for operating. Authorization is by the Provincial Bureau of Artificial Persons and consequently no intervention of the national jurisdiction is required. One advantage is that it is unnecessary to amend its by-laws when the number of association members is modified. If it becomes necessary to amend the by-laws, the respective approval procedure would be carried out in the province with little delay. It would operate as a civil entity thereby avoiding a considerable tax law structure which would do nothing but increase the energy costs for the users and render the organization's management more complex.

Labour Relations

It was proposed at the work meetings to define a role distribution among the organizations taking part in the Plan which would allow transfer of HMPP operation and maintenance activities to the user association and thus reduce exploitation phase costs. The cost reduction would naturally only take place as long as the transfer did not require having employees. According to labour laws, employees have the right to join the respective Collective Bargaining Agreement which in this case would be that of the Argentina Federation of Light and Power Workers. It was proposed that those activities, which due to their continuity and complexity require the use of employees, shall remain under MOSP jurisdiction. Whereas those activities transferred to the other user association shall be handled in accordance with the user self-management criteria or, if third-party intervention is required, shall be subject to construction contracts and/or contracts for services.

Organizational and Methodological Background

Need for an Execution Unit

The diagnosis developed in Chapter 10 made evident the low level of coordination and precision in the technological development stage of the HMPP programme in Misiones. The Expansion Plan requires an organizational approach which may overcome the present limitations. The MOSP within Misiones Province is the application authority as regards the Water Act, and therefore the plan execution shall develop under its jurisdiction. There was ample consent at the work meetings regarding the idea that the Expansion Plan should be handled by an Execution Unit which might, within the ambit of the MOSP, concentrate and coordinate the large number of activities involved in the different phases thereof. Since the works are multiple purpose ones, the Execution Unit shall coordinate human resources from different organizations and carry out multidisciplinary activities. The most outstanding activities, however, shall be those related to the electricity supply purpose of the works.

The alternative was then raised as to whether the Execution Unit should depend directly on the MOSP or be organized within the scope of EDEMSE. Direct dependence on MOSP is the more interesting alternative since it offers a better solution to the multidisciplinary coordination problem posed by implementation. Dependence on EDEMSE has not been dismissed as a solution as long as it is given sufficient hierarchy and autonomy to operate efficiently in implementing the plan. Both alternatives are equally valid in light of the main finance alternatives—loans from development banks and contributions from international cooperation.

Regardless of the hierarchical subordination to be adopted for the Execution Unit, it shall be established on the basis of the human resources and know-how available at CREDHMI, EDEMSE and APOS. These three organizations are closely related to MOSP; thus the transfer of personnel and know-how may be quickly and simply effected.

CREDHMI contributions are in the water resource survey and in the areas of basic and detail engineering for the sealing, intake and conduction systems, and the HMPP electromechanical equipment, as well as in the HMPP construction direction and in the technical assistance for their operation and maintenance. CREDHMI has, in addition, a solid experience and qualified human resources for performing the social evaluation of HMPP feasibility; it may contribute in the final design and processing of the normative instruments required by the Plan. EDEMSE, besides sharing human resources of the Non-Conventional Energy Department with CREDHMI, may add specialists and know-how to the project, construction, operation and maintenance of rural distribution networks and contribute likewise in the area of the economic and financial management of the plan. APOS can contribute basic and detail engineering for intaking, driving and storing water for households; production applications; direction for construction and technical assistance for operation and maintenance.

The Plan needs a higher degree of maturity before constituting the Execution Unit. The objective is to negotiate and obtain a financial support basis for the Plan, the solution of which is the largest and most significant restriction detected. To this end, it is necessary to prepare technical and economic documents in the format required by the finance sources. It was agreed on that these activities would be performed by CREDHMI, which was created within the scope of its present by-laws, as the Divulgation Area. CREDMHI's activity plan for 1989 puts the emphasis on the continuity of the action taken in relation to the supply plan formulated in the RETAIN project and on the need to begin negotiations which will obtain other finance sources for the programme from the national government, international organizations or the private sector.

Execution Unit Internal Organization

The Execution Unit shall centralize to a large extent the activities corresponding to Phases I and II of the Plan, changing its role to coordination, assistance and control duties during Phase III where the management, organization and maintenance are to be distributed among user associations and specialized groups. The basic organization of the Execution Unit for Phases I and II is divided into three operation areas (project and works, administration and finance, works transfer) and an administrative assistance section.

The project and works area is to identify, design, construct, put in operation and deliver on a 'turn key' basis the set of HMPPs comprised in the Plan. It will identify the potential

HMPP sites; perform the technical, economic and social evaluation of each identified potential HMPP; draw up the final preliminary plan, the technical specifications for their components and the budget for the pre-selected HMPPs. It shall plan the contracting and execution of the works, equipment and installations and assist the administrative area in the accreditation of suppliers and contractors in evaluating the proposals submitted by them; inspect and follow-up construction and perform the industrial start-up test; produce all the documents for each HMPP, including the demarcation drawings of the whole area.

Pre-requisites for the project and works area are methodological guidelines for identifying and selecting projects; cartographic and census information; criteria developed by CREDMHI-IDIP (Engineering School) for the standardization of turbines and civil and conduction works which will expedite the preparation of preliminary plans and their evaluation (see Muguerza and Bordon, 1983); a quality assurance and supplier accreditation programme for those components which are not normally provided in the market.

The objective of the administration and finance area is to obtain and administer the funds required for outfitting and financing the Execution Unit and for the project, construction, start-up and transfer of all the HMPPs in the Plan. Activities are to negotiate for financial assistance and prepare technical documents (banking projects, technical files, evaluation studies) with the help of the Project Area and of specialized institutions. (CREDMHI, as part of the activities preliminary to the making up of the Execution Unit, signed a cooperation agreement with the Institute of Energy Economics with a view to receiving cooperation in the preparation of these documents.) It is also to draw up agreement documents; draw on the obtained resources in accordance with the rules stipulated in the loan or donation agreements and administer their application in accordance with the rules in force at the MOSP. In addition, it shall draw up the payment agreements (with users signing the acceptance memorandum) and collect the corresponding advance payments, both of which shall be done with the assistance of the social area. With the technical area, it shall coordinate the payment terms for each supply, and it shall carry out competitive biddings, award analyses, contracts and payments.

Pre-requisites are the administrative and accounting rules to which the application of the plan resources shall be subject. At the work meetings it was agreed that it would be convenient to use flexible rules of the type in force for the MOSP decentralized agencies. It must also have at its disposal the drawing schedules arising from the investment plan to be prepared by the Project and Works Area.

The works transfer area is to organize and train users; as well as draw up, apply for and keep up-to-date documents required by the rules for HMPP transfer and exploitation. Activities are to draw up the memoranda of agreement between the MOSP and the beneficiaries of each HMPP; draw up standard by-laws; prepare documents proving each user's payment obligation; negotiate on behalf of the MOSP the expropriations, transfers, establishment of rights of way and rights for the passage of water and electric conduits; draw up concession agreements; draw up the ordinary basic rules which must be contained in the internal regulations for HMPP use and exploitation; organize and implement, with the internal assistance of the project and works and the administrative areas and the external assistance of the Engineering School, the user training plans for HMPP operation and maintenance, the rational electric energy consumption, safety in the use of facilities and the association management procedure.

Pre-requisites are the list and social evaluation of the users who will be included in the memorandum agreement of each HMPP and the technical and cadastral documentation of the area.

Administrative support should go to all task areas. It shall centralize all documentation typing, recording, filing, photocopying and communication activities.

Pre-Investment Phase Guidelines

The steps prior to the incorporation of HMPPs into the plan must combine technical, economic and social aspects in an analysis process which goes from the identification of a possible site to the signing of the memorandum of agreement with the potential users and the preparation of the bidding documents. Increasingly complex studies and evaluations will allow decisions as to whether the identified project is to be continued or dismissed.

During the first phase of the RETAIN Project a method was developed for analyzing the investment plans for the supply of electricity to depressed rural areas which analyzes and compares different technical solutions on micro- and macro-economic scales. The methodological guidelines for the technical/economical evaluation of HMPP are sufficiently developed in that study.

In the area selected for developing the plan, two basic situations lead to the assumption of HMPP competition in the electricity supply. First is the weak electrical infrastructure at the subtransmission level which makes it difficult to expand the rural distribution networks. Second is the high degree of HMPP penetration disclosed by the market research (see Chapter 11).

RETAIN Phase I studies produced a number of indicators which permit pre-evaluation of the technical/economical feasibility of HMPP projects. Sites which do not allow power ratings higher than 10 KW shall be rejected. In the higher areas of the basins where there are low flow contributions (lower than 40 liters/sec.) and drops which do not exceed 20 metres, the sites presenting very open closure sections shall be refused since they will require very costly dams to ensure HMPP daily regulation. In the low basin areas having good flow contributions (higher than 200 liters/sec.) and, consequently, little influence of the sealing works on the cost, only those sites requiring the installation of conduits on gradients of less than 5° shall be rejected. Concerning single-phase voltage lines, rejected sites are those with less than three users/km of line.

Those sites exceeding the minimum requirements will be in a position to reach the executive preliminary plan level in their technical definition. In this stage, the engineering studies must be complemented with social ones.

The determination of the technical feasibility of a micro-hydroelectrical undertaking is in no way sufficient to make decisions regarding its actual execution. An essentially important point for guaranteeing investment efficiency is an evaluation of the potential user population with regard to a number of relevant characteristics in order to decide on HMPP construction. These characteristics are comprised in the following steps:

1. To determine whether there is, in the neighbourhood, a sufficient number of inhabitants to be supplied with electricity.
2. To consider the potential users' payment ability which must be understood as a combination of economic resource availability and willingness to pay improvement contributions (investment) and user association expenses (operation and maintenance).
3. To evaluate the organizational ability of the users as a collective subject who, organized as a conventional person (user association), shall take charge of the works.
4. To ensure the future users' formal commitment to assume the responsibility which will fall to them if the decision is made to carry the undertaking into effect.

This process should be carried out without arousing great expectations in the population since the works would not be performed if the evaluation is negative.

Although procedures suggested here cannot guarantee 100% success of a certain project, they should minimize the failure probabilities which can be ascribed to non-technical factors. There exist two alternative ways of solving the evaluation issue within the scope of HMPP based rural electrification plans for a specific area. The probablistic procedure consists of globally assuming a certain percentage of 'losses' due to non-evaluated factors. This is equivalent to lack of evaluation. The punctual procedure tends to determine with the highest possible reliability the fulfilment of the requirements expressed for each hydroelectrical undertaking.

The probablistic procedure has several drawbacks. From a social viewpoint, there is the cost of involving a number of inhabitants in unfeasible projects. Moreso, there is no empirical knowledge to quantify the success probabilities of the projects. The punctual method, in turn, may become excessively troublesome and expensive to carry out, if no limits are fixed regarding the degree of detail with which each project evaluation is to be approached. These two methods are representative of the extremes of a continuum comprised of several intermediate possibilities. The decision-making concerning the execution of a project is a process which develops through several successive stages. The process is not merely linear; each stage turns into feedback in terms of which process proceeds into the following stage or not.

Stage I: Preliminary Desk Studies

In this stage, work will be done on a department scale in order to carry out a first identification and selection of interesting sites. By means of a planimetric study, basins, drops, channel lengths, flow modules and constant power ranges shall be calculated. The sites shall be checked by means of the aerial photographs available at the province's Cadastral Bureau. Through Population and Housing Census information, the number of potential users in the surrounding area will be estimated. Based on information supplied by the Ministries of Public Health and Education, the schools and health centers having no electric energy will be located. The outcome of this stage will be a selection and hierarchy of the sites identified on the desk and an activity schedule for the first field study.

Section 2: Preliminary Field Studies

At this stage, the interesting locations selected on the desk shall be checked in the field and a more accurate determination made of the capacity that may be installed and of the number of potential users to be supplied. The field verification of the existence of the resource (flow/drop) must be associated with the existence of inhabitants in the surrounding area. The very definition of 'surrounding area' is essentially technical/economical in nature: if the lines from the microturbine reach far enough, users will always be found. But at what cost? It is not evident that the number of users is always adequate for the technically identified project. In this situation there are three logical possibilities: The number of potential users in the surrounding area is too low (and in this case the project is definitely given up). The number of users is within the established limits (and the project proceeds on to stage 3). The number of users exceeds the highest limit established in terms of the available power. Here too the project may proceed to Stage 3, but the 'surrounding area' shall be redefined by making it more reduced and the redefinition should not be exclusively based on technical factors such as the quantity of kilometers of line to be laid.

Stage 2 may be exclusively covered by engineering personnel. The output of this stage should include the preliminary definition of the HMPP technical parameters, the capacity which may be installed, cartographic delimitation of the potential area and the location of all users (detailing the types of users, household units, schools).

Stage 3a: Characterization of Potential User Categories

This consists of a quick survey of all the inhabitants of the surrounding area to obtain information on basic social and economic characteristics, degree of settlement 'eventual' interest in becoming electrified and expectations regarding the use of electricity, energy and electric power requirements in a medium term, payment ability, formal and informal social relationships (leadership and pre-existing institutions).

This stage must be complied with by specialized personnel from the social area. Surveys and interviews are required.

The output of this stage should include an estimate of the future users' energy requirements, payment ability and organizational potential from which there may derive a qualitative judgement on the project pros and cons and a preliminary classification of users per power category. If the area dealt with is one having more potential users than those which may be supplied, the output should include a recommendation on the redefinition of the surrounding area.

Stage 3b: Primary Preliminary Project

Simultaneously with the user characterization effected through field and desk work a primary preliminary project shall be made to determine final site and topographical survey of the sealing and intake works, alternative sites for the engine-house, topographical survey of alternative routes for conduction channels and piping, expeditions inspection of the area to be flooded in order to determine the limitations to the maximum sealing height, raw material supply sources for sealing works. On the basis of field information, the type of sealing to be used and the range of heights (maximum and minimum) admitted by the project shall be determined. Thus, with the alternative conduction routes, the range of constant power which may be obtained from the site under acceptable cost conditions can be determined.

Stage 3 studies shall be harmonized in an interdisciplinary way to force a second adjustment between power and energy to determine the capacity to be installed in the power plant in accordance with the requirements of each user as defined per the power category specified for them by the social evaluation. On this basis, the final sealing height, conduction route and engine-house site may be adopted. If the HMPP maximum power offer is lower than the requirements, users should be pre-selected before proceeding on to the promotion stage.

Stage 4: Project Promotion

The point here is not to develop a 'sales strategy' in the way profit-seeking commercial enterprises might do. The future users' conviction must be genuine and based on an individual and overall evaluation of the objective profits and drawbacks of the proposed technology. It must also be clear that the decision on project execution falls to its users. All coercion shall be avoided by first submitting the proposal to individuals; many of them may feel compelled to agree in a group situation in which they find it difficult to refuse and then later not give any effective assistance to the project.

The strategy promotion shall rest on individual invitations to potential users in a proposal submitted by means of an interview. On the basis of the survey information, the feasible expectations are encouraged and the unfeasible ones discouraged. The extent of the responsibility to be assumed by the user is explained. A meeting with all potential users is called for the following day.

At the users' meeting the project technical characteristics are summarized. The emphasis is on consumption limitations as well as possible electrification profits. All the questions raised by the project are answered. The responsibility which will fall to the group of users as regards works construction and the system operation and maintenance is emphasized. A set of rules for the group organization is proposed. The meeting ends upon the signing of a memorandum by each of the future users expressing the will to carry out the process. The memorandum is signed in duplicate. A copy remains with the Project Execution Unit and the other with the group of users organized under the institution they decide on.

The output of this stage is the decision to carry out the project formalized in the memorandum signed by the future users, as well as a tentative plan for training them in the technical, organizational and administrative accounting aspects. The memorandum shall mention the personal data of each interested party, the cartographic location of the place where the same shall be supplied and the power category to be joined.

Stage 5: Approval of Final Preliminary Projects

The outcome of the promotion stage will determine whether it is necessary to introduce any modification into the sealing and conduction system technical parameters. It will allow definite adoption of the HMPP electromechanical equipment power module and the distribution system route from the power plants to the user connections.

Finally, the projects whose technical and social feasibility have been accredited shall, grouped in zones within each department, be submitted to a comparative economic evaluation with the centralized system network extension. To that end, the cost data bank developed in the RETAIN Project shall be updated maintaining the criteria to evaluate each alternative through the Equivalent Annual Cost (EAC) at accounting prices. These comparative studies were coordinated with the Rural Electrification Department of EDEMSE and will allow the compatibility of the different technologies in energy provision.

After the Execution Unit submits a report on the results of the pre-investment studies, MOSP will authorize the start of the investment stage for the HMPP included in each zone into which the departments have been divided for evaluation purposes.

Investment Phase Guidelines

The HMPP expansion plan has some features which distinguish it from other public works construction plans. They have two components, turbines and regulators, which are not normally supplied in the market and for which it is necessary to develop local suppliers who may in future do repairs and furnish new supplies. The warranty of pre-established quality and efficiency are required as to the supply of these components. The local impact of investments is sought to be maximized by permitting small- and medium-size building companies residing in the province to participate. Capital requirements are sought to be reduced through the participation of provincial and municipal public agencies and the user associations in the works construction. It is necessary to manage a large number of scattered works in which a large number of trades (specialities) participate simultaneously.

The technological management of the Plan is based on two main courses: To organize a quality assurance programme fixing the rules to which both the suppliers and those responsible for the follow-up during the construction and equipment start-up must respond; and to perform the technological disaggregation of the works package making up each approved plan section (packages of about ten HMPPs). Technological disaggregation is advantageous in that the contracts are made per specialist, but it also has the disadvantage that a greater Execution Unit effort is required for coordinating the supplies and engineering assembly.

In the case of turbines and regulators the programme assumes that the projects performed by the Execution Unit and the manufacturing carried out by the local suppliers shall wholly adjust to the design, detail engineering and standardization criteria developed within the scope of the CREDMHI-IDIP agreement. To that end, MOSP and/or the local suppliers shall enter into specific technology transfer agreements with the other institutions and persons who are the joint owners of the developments (Engineering School, Energy Secretariat and researchers). It was deemed convenient that the quality assurance programme for turbines and regulators be supported by the external assistance of the Engineering School.

The quality assurance programme for turbines and regulators involves an orderly set of activities going from the period prior to the making of the contracts up to the industrial exploitation of the purchased equipment. These activities determine the equipment type and quality and the qualifications of the human resources a company must have for producing the equipment to be purchased. Another activity is to find and pre-assess the companies which due to the interest they arouse and their resource potential are in a position to be suppliers. Technical advice is given to the pre-assessed companies and they are finally assessed or excluded from the programme. The quality control rules and standards for manufacturing, assembly and admission are systematized. Documents shall be issued specifying the time and standards for the examinations, and the acceptance or rejection standards shall be known by the suppliers. Permanent assistance shall be given to suppliers in the assessment and manufacturing stages to allow them correct interpretation of manufacturing and assembly methods as well as control standards. For those components normally supplied in the market, standards shall adjust to the ones usually applied by MOSP.

The technological disaggregation of each HMPP series implies separating each HMPP into its component parts and then grouping components and/or tasks having the same technical characteristics and contracting said sets of similar supplies. This method will reduce contracting prices, adequately distribute the supplies among locally-based and national companies and have the government agencies and the user associations participate in the investment stage, ensure a direct relationship with suppliers who specialize in each technological branch and consequently, attain higher quality levels.

This method requires a greater effort in contracting, follow-up and admission negotiations, as well as in the assembling of parts and components from different suppliers. Consequently, the points of contact between the suppliers must be accurately specified from a technical viewpoint. In addition, the equipment manufacturing, work construction and equipment and installation erection terms must be carefully programmed and controlled.

The transfer of the works requires the assurance that the community receiving the works, which has demonstrated its interest during the promotion stage and actively participates in the investment stage, is trained in the handling of the installations and in the rational use of electric energy.

The training process should take place during the works construction and should deal with safety standards for the use of electric energy, operation and maintenance of the microturbine and its complementary installations, legal requirements to be complied with for institutionalizing the group of users, accounting techniques and procedures for the collective solution of conflicts which may arise between group members. The training process can be carried out by virtue of an agreement with the School of Engineering and School of Social Sciences. It shall be organized by means of reading material suitable for users' education level and complemented with meetings held in each HMPP location area.

At this stage the personnel having sufficient ability and skills for operating and maintaining the power plant shall be selected. They may then complete their training at specially prepared installations in the School of Engineering. The outcome of this stage should be a user group in a position to take charge of the Project.

Exploitation Phase Guidelines

The organizational forms and methodological guidelines to be adopted for the exploitation phase will depend on evaluations and decisions made during the development of the earlier phases of the plan. However, it is necessary to take into account some basic guidelines. It is advisable to decentralize the exploitation phase activities, turning the Execution Unit into the Coordination and Control Unit once the investment period is completed. The activity centre shall now be a user association which will be in charge of the operation and the light maintenance of each HMPP. Assistance to the user associations, given during the exploitation phase, has three main components—technological, social and administrative. All the technical assistance activities may be decentralized by assigning them to specialized departments of EMSA, the service cooperatives and APOS in matters related to electricity distribution networks and water supply installations. The private sector and the university can deal with matters related to HMPP electromechanical equipment. The social and administrative assistance activities may likewise be delegated through an agreement with the university and municipalities of the HMPP location area.

The control activities must be reserved for MOSP. These activities, as far as user behaviour is concerned, should be primarily delegated to association authorities. MOSP might act directly if its intervention is requested by association authorities. MOSP would keep all the control activities related with the compliance by the user associations of the concession agreement and its associated rules. It would also intervene in conflicting situations which may occur between the associations and third parties.

The user associations shall adjust their operation to a general normative background, but they will have autonomy regarding the setting down of their own regulations and, particularly, for defining the terms and ways of payment for the users' contributions destined to support the HMPP operation and maintenance activities, for selecting the personnel in charge of the same and for determining the manner of payment of the activities.

So that a decentralized organizational structure may be efficient in its assignation, it is necessary that the coordination role to be performed by MOSP be supported by assistance agreements with all the organizations and companies which will participate in the execution of the activities of this phase. Furthermore, a radio and telephone communication system must be implemented which may facilitate quick intervention in cases of technical failure at the HMPP or in conflicting situations occurring at the heart of the associations and capable of disturbing normal service.

Finance Strategies

Financing of Transition Costs

The transition from the present demonstration stage in the HMPP utilization to the mass application of this technology according to the market prospects analyzed in the expansion plan, involves a series of costs which must be considered in addition to the costs directly related to the investments. Said transition costs involve all the pre-investment activities, as well as the technical, economical, legal and social management activities during HMPP construction, start-up and transfer.

For the Expansion Plan, transition costs are the ones derived from the organizational and methodological guidelines. Thus, to the Execution Unit personnel and outfitting costs must be added the operating expenses corresponding to the field and desk tasks directly undertaken by the Execution Unit and the tasks performed, by virtue of an agreement, with the support of third parties, such as the finance negotiations and the equipment and component tests and inspections.

On the basis of consultations with the New Energy Source and Preservation Bureau of the National Energy Secretariat and international cooperation organizations (CIDA and GTZ), it is possible to assume that a partial financing of the transition costs is obtained through non-refundable amounts contributed by such institutions. MOSP, partly by assigning personnel from its own organizations and partly through an agreement with the Schools of Engineering and of Social Sciences, may cover (without incurring large expenses) a significant portion of the expenses forecasted for human resources.

Financing of Investments

According to the market estimates set forth in Chapter 11, the forecasted total investment amounts to approximately US$12,500,000. This results from the construction of 160 micro power plants for supplying 4,413 users with a total installed capacity of 3,600 KW. It is inferred, from the estimation of the possible locations and the available resources, that, out of the total number of power plants, 112 will be 15 KW ones and 48 will be 40 KW ones and they will respectively supply 1,572 and 2,841 users.

The investment phase covers a five-year period up to the completion of supply for the 4,413 users. It was deemed reasonable to start said period by constructing 26 micro power plants in the first year and finish it by constructing 48 in the fifth year.

The users capacity to absorb part of the electric energy supply costs acknowledges two origins: Their saving capacity and the express wish to devote part of said savings to meeting the energy requirements; and the resources available on account of the substitution of other sources (kerosene, liquefied gas) by electricity. It has been assumed that the users will devote the resources available from source substitution to covering the electric generation system operation and maintenance costs. Consequently, their saving capacity will allow them to contribute to the investment costs through the improvement contribution procedure.

At the close of each project promotion stage, each user will have defined the power level desired for subscription. Since each power category corresponds to an improvement contribution value (0.4 KW: nothing; 0.8 KW: US$120/yr; 1.6 KW: US$240/yr), the users will define the compromise between their electric energy requirements and the fee they are willing to pay. For the purpose of financial projections, it will be assumed that users will act strictly in accordance with the payment ability analyzed in the present study. Thus, on the basis of the Housing Condition Index structure of each department, it may be determined that the annual payment ability per department will be as indicated in Table 12.3.

Table 12.3 Annual Payment Ability per Department (US$)

	Cainguás	25 de Mayo	Guarani	Iguazu	Belgrano	San Pedro	Total
A	4,846	4,901	4,842	724	2,453	2,454	20,221
B	115,344	82,580	135,448	20,103	53,971	67,489	474,935
C	56,445	26,850	77,908	11,795	31,956	40,430	245,383
Total	176,635	114,331	218,198	32,622	88,380	110,373	740,539

As can be seen from Table 12.3, the total annual payment ability amounts to US$740,000, which is deemed to be the maximum contribution that potential users can make to the financing of the investment plan. Moreover, it is anticipated that users may start contributing once they have the corresponding service. It is consequently estimated that only in the sixth year of the programme will the contribution reach its maximum value: that is to say, when all of the users have their electricity supply. In this way, the users' annual contribution would follow a progressive pattern from US$121,002 in the second year to US$730,138 in the twenty-third year.

The proposed investment programme may be financed through internal funds or external financing. For the purpose of the present study it has been anticipated that 50% of the investment might issue from the regional development banks, whereas the rest would proceed from the Special Inland Electric Development Fund (FEDEI).

The loan which may be obtained from the regional development banks fits into the type of loans granted for multiple works programmes which, according to the regulations in force, will be estimated on a fifteen-year term basis with three years of grace and an 8% interest rate.

The bank's total contribution would amount to US$6,249,600 without intercalary interest, which, in accordance with the forecasted terms and interests, implies an annual US$730,138 instalment. The whole of the financing granted by the Regional Development Bank might be absorbed by the contributions of the system users. As a matter of fact, it was possible to define an instalment for the users as from the start-up of the first microturbine group (year 2). The funds thus generated cover all of the intercalary interests up to the beginning of the loan repayment, and they even produce a surplus. As from the ninth year, the users' contributions may also absorb the loan repayment instalments.

FEDEI permits granting repayable loans of preferential rates and on extremely advantageous terms, as well as non-repayable loans. For the purpose of the present study, it is assumed that the whole of the funds shall be repaid. The credit which FEDEI has usually granted to electrical cooperative societies (applicable in this case to user associations) has a 6% annual interest rate and repayment terms ranging from 10 to 15 years.

FEDEI's contribution, together with the users' contribution during the investment period, will complete the financing of the Plan investment costs. FEDEI's resources do not generate intercalary interests, but they should begin to be repaid as from the sixth year. The financing would consist of a 15-year term loan with an annual 6% interest rate. According to this hypothesis, the debt repayment will amount to US$602,256 per annum as from the year following that on which the investment programme ends.

Thus, the investment resource flow will be made up as indicated in Table 12.4.

Table 12.4 Sources and Applications of Investment Funds (US$)

Destination	Investment					
Origin	1	2	3	4	5	Total
Development Banks	1,024,240	928,760	928,760	1,510,320	1,857,520	6,249,600
FEDEI	1,024,240	889,697	653,625	1,395,155	1,686,546	5,849,263
Users*	0	39,063	75,135	115,165	170,974	400,337
Total	2,048,480	1,857,520	1,857,520	3,020,640	3,716,040	12,499,220

* Surplus after paying for the Regional Development intercalary interest amounts.

Whereas the total debt (Development Banks-FEDEI) repayment would be met up to 57% by the users and the remaining 43% by resources from another origin, 100% of the intercalary interests amounts would be paid for by the users.

The proposal set forth does not dismiss the consideration of other possible sources of financing or the possibility of contractual varieties implying association with either local or foreign companies which may contribute to the investment financing. Also following a conservative pattern, the possible financing by suppliers has not been included since the terms and interest rates they could offer would not be the most convenient ones for the proposed programme. On the other hand, there is the possibility of obtaining non-repayable funds from FEDEI itself or through international development agencies which would help to lessen the investment burden on local funds. As has been demonstrated by former examples, it is possible, by using bilateral cooperation agreements, to develop projects through joint-venture type associations in which the foreign partner contributes technology and partially takes over the project financing. These financing strategies should be more thoroughly analyzed when carrying out the studies for the final preliminary project.

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