Brazil

Rural Electrification with Renewable Energy Systems in the Northeast: A Preinvestment Study

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ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) is a special global technical assistance program run as part of the World Bank's Energy, Mining and Telecommunications Department. ESMAP provides advice to governments on sustainable energy development. Established with the support of UNDP and bilateral official donors in 1983, it focuses on the role of energy in the development process with the objective of contributing to poverty alleviation, improving living conditions and preserving the environment in developing countries and transition economies. ESMAP centers its interventions on three priority areas: sector reform and restructuring; access to modern energy for the poorest; and promotion of sustainable energy practices.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (ESMAP CG) composed of representatives of the UNDP and World Bank, other donors, and development experts from regions benefiting from ESMAP's assistance. The ESMAP CG is chaired by a World Bank Vice President, and advised by a Technical Advisory Group (TAG) of four independent energy experts that reviews the Programme's strategic agenda, its work plan, and its achievements. ESMAP relies on a cadre of engineers, energy planners, and economists from the World Bank to conduct its activities under the guidance of the Manager of ESMAP, responsible for administering the Programme.

FUNDING

ESMAP is a cooperative effort supported over the years by the World Bank, the UNDP and other United Nations agencies, the European Union, the Organization of American States (OAS), the Latin American Energy Organization (OLADE), and public and private donors from countries including Australia, Belgium, Canada, Denmark, Germany, Finland, France, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Sweden, Switzerland, the United Kingdom, and the United States of America.

FURTHER INFORMATION

An up-to-date listing of completed ESMAP projects is appended to this report. For further information, a copy of the ESMAP Annual Report, or copies of project reports, contact:

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BRAZIL

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Preface and Acknowledgments

This ESMAP study was a response to a request by the Bank's Latin America and Caribbean (LAC) Regional Office for support in designing an innovative project to deliver energy services to dispersed rural areas of Brazil. The project was to be based on (1) the expanded utilization of renewable energy systems and (2) strong participation by the private sector. The concept—first proposed in an "idea paper" prepared by LAC staff in mid-1996 on the basis of a Winrock-sponsored report by the Institute for Sustainable Development and Renewable Energy (*Instituto de Desenvolvimento Sustentável and Energias Renováveis*, or IDER)[1]—is to develop the project first in a few states in Brazil and then use the experience in new regulatory and implementation mechanisms to replicate the program sustainably in other areas. The objective is to address the likely adverse consequences of the privatization of the state power utilities on incentives for investments to supply essential electricity services to the dispersed, low-income population in rural areas of Brazil.

In a Bank/ESMAP mission to Brazil in August 1996, agreements were reached with the Ministry of Mines and Energy to prepare a package of preparatory studies of off-grid areas in Bahia, Ceará, and Minas Gerais, the selected initial states. To supplement ESMAP's resources for the activity and avail of in-country expertise, an alliance was forged with the Winrock Renewable Energy Project Support Office (REPSO) in Salvador, which office is partly financed by the U.S. Agency for International Development (USAID). Winrock REPSO would organize focused studies analyzing alternative delivery and financing mechanisms, determining the legal and regulatory framework within which the proposed project could be implemented and reviewing the availability of solar and wind energy data in the subject areas.

Consequently, Hagler-Bailly was commissioned by Winrock/USAID to undertake the studies on alternative delivery mechanisms and on the legal and regulatory framework. Winrock REPSO itself conducted a review of existing financing mechanisms and agents in the country. The National Renewable Energy Laboratory (NREL) prepared a review of existing data on solar and wind regimes.

Later, ESMAP obtained support from the French Government that enabled French consultants (CIRED-CNRS/WBI) to conduct quick market characterization surveys in the three states, estimating the market sizes for solar photovoltaic (PV) applications in households, public service centers and small businesses. The results and recommendations of the draft reports were discussed by experts from Brazil and South and North America at a workshop during the August 1997 Renewable Energy in the Americas (REIA) meeting in Rio de Janeiro (see the workshop program in Annex A). The studies allowed ESMAP to help prepare a detailed Project Concept Note (PCN) and later a Project Concept Document (PCD) for the LAC region.

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1 IDER, *Brazil Renewable Energy Program: Potential of Sustainable Projects; Preparatory Study for Supply of Rural Energy Using Renewable Energy*, prepared for Winrock International (Fortaleza, Brazil, July 1996).

This report was written by Anke Meyer, Ernesto Terrado, Keith Kozloff, Christophe de Gouvello, and Osvaldo Soliano Pereira, and summarizes the findings of the full ESMAP activity. It was prepared partly from the results of several field missions, as documented in aide-mémoires and back-to-office reports. Its main sources, however, were the excellent reports submitted to USAID and the Bank by Christophe de Gouvello and Marcelo Poppe (market characterization study), Osvaldo Soliano Pereira (existing financing and subsidy mechanisms), and Keith Kozloff (alternative deployment mechanisms and policy framework). The present document draws freely from these reports, which are listed in Annex B. During the course of this activity, primary and summary information has been generated and assembled that has not previously been easily accessible. The annexes contain some of this information, which is relevant to renewable and rural energy activities in Brazil.

The information on which this report is based was gathered until the end of 1998. Important developments—such as the recognition of the concessionaire, subconcessionaire, permissionaire and authorization concepts by ANEEL—have occurred since then that would facilitate implementation of the kind of projects the report describes.

Overall, many agencies and individuals contributed to the work, including Luis Vaca Soto of the Bank LAC Region Finance, Private Sector and Infrastructure Sector Unit, Eugenio Mancini of the Ministerio de Minas e Energia/Program for Energy Development of States and Municipalities (MME/PRODEEM), Jeff Seabright of USAID, William Howley of Winrock REPSO, and Benoit Loutrel, Assistant to the Executive Director for France at the World Bank. Their support is gratefully acknowledged.

Abbreviations and Acronyms

ANEEL	National Agency of Electric Energy
APL	adaptable program loan
BNB	Banco do Nordeste do Brasil
BNDES	Banco Nacional de Desenvolvimento Econômico e Social
CCC	Conta de Consumo de Combustíveis
CEMIG	Companhia Energética de Minas Gerais
CEPEL	Centro de Pesquisas de Energia Elétrica (Brazilian Electric Research Center)
CFL	compact fluorescent light
CHESF	Companhia Hidro Electrica do São Francisco
COELCE	Companhia de Eletricidade do Ceará
COELBA	Companhia de Eletricidade do Bahia
DNAEE	National Department of Water and Electric Energy
DNDE	National Department for Energy Development
ESCO	energy service company
FOB	free on board
FTV	Fundação Teotônio Vilela
GEF	Global Environment Facility
GOB	Government of Brazil
IBGE	Fundação Instituto Brasileiro de Geografia e Estatística
IDB	Interamerican Development Bank
IDER	Instituto de Desenvolvimento Sustentável and Energias Renováveis
IPP	Independent power producer
IRR	Internal rate of return
LPG	liquid petroleum gas
MME	Ministerio de Minas e Energia
MV	Medium-voltage
NGO	non-governmental organization
NREL	National Renewable Energy Laboratory
O&M	Operations & maintenance
PCD	Project concept document
PNAD	Pesquisa Nacional por Amostra de Domicílios
PRODEEM	Program for Energy Development of States and Municipalities

PROERNE	Programa de Energia Renovável do Nordeste
PV	Photovoltaic
PMU	Project management unit
REP	Renewable energy project
REPSO	Winrock Renewable Energy Project Support Office
RES	Renewable energy system
RET	Renewable energy technology
RGR	Reserva Global de Reversão (RGR) or Global Reversion Reserve
SDC	Solar Development Corporation
SEBRAE	Brazilian Service of Support to Small Enterprise
SELF	Solar Electric Light Fund
SHS	solar home system
SMSE	Sustainable Markets for Sustainable Energy (IDB program)
SNSI	National System of Subsidy for Isolated Systems
TJLP	long-term rate of interest
USAID	U.S. Agency for International Development
WTP	Willingness to pay

Units of Measure

km	Kilometer
MW	Megawatt (= 1000 kilowatts = 1 million watts)
MWp	Megawatts-peak
W	Watt
Wp	Watts-peak

Currency Equivalents

June 1997: US$1 = R$1.076
June 1999: US$1 = R$1.793

1

Introduction

The Problem

1.1 In the 1990's the Government of Brazil introduced significant structural economic reforms, including trade liberalization, deregulation, and privatization. The reforms are now in a considerably advanced state of execution. In the power sector, although the process is ongoing, many federal and state-owned assets have already been privatized. A new regulatory agency, the National Agency of Electric Energy (ANEEL), was created and has been functioning since 1997. The new private electricity distributors are expected to improve the delivery of services to their principal markets, namely, the residential and industrial customers connected to the grid distribution system.

1.2 Against this backdrop is the situation in rural markets, where a substantial number of households, community centers, and small businesses are still unserved with electricity because of their distance from the distribution lines, the high cost of conventional electrification solutions and the general poverty in these remote areas. It is estimated that about 12 percent of the country's population, or about 20 million customers, remains unserved. In the three states of Bahia, Ceará, and Minas Gerais alone, where the present study has focused, more than a million households are expected to remain unelectrified in 2005 and are not likely to be electrified conventionally in the foreseeable future.

1.3 In the past, special programs—subsidized by the federal and state governments as well as bilateral donors, and implemented by the previous state-owned utilities—tried to provide electricity service to populations in dispersed areas through the use of decentralized systems, most of them based on renewable energy. These efforts were severely limited by lack of resources and failure to design cost-recovery systems in the projects (see Annex C for information regarding subsidies for off-grid and grid-connected customers). Although some of the new private state utilities are reportedly allocating some of their profits to modestly continue rural electrification, in general the market-driven orientation of these enterprises will limit attention to rural electrification in general and in dispersed rural areas in particular.

1.4 The Government of Brazil has indicated that the fight against poverty and inequity is its central priority in the medium term. It considers access to modern, reasonably-priced energy a key element of its overall poverty alleviation efforts. So far, the most important national initiative in this regard is the Federal Program for Energy Development of States and Municipalities (PRODEEM) of the Ministry of Mines and Energy. PRODEEM finances the installation of community-oriented applications such as water pumping systems and electrification of schools, health clinics, and other facilities, and has been able to demonstrate the technical viability of renewable options on a pilot scale. Despite the vital contributions expected of and already made by the Program to the improvement of dispersed communities, its effectiveness has been limited so far by its total dependence on public funds. Program funds are designed primarily for community-oriented applications, and other funds will have to be leveraged in order to address the electrification needs of the households that constitute the largest part of total demand in these areas.

1.5 To improve electricity access in dispersed areas in the long term, a commercially sustainable dissemination activity is needed. It should be carried out by and with equity from the private sector, through a system of incentives that assures fair returns to private participants while minimizing government subsidies. The coverage should include productive applications, community-oriented or public service applications, and residential applications. An optimal mix of subsidized and unsubsidized market segments and a critical total mass of potential customers are the key ingredients that could attract private investors in the dispersed area market. This type of effort is consistent with the Bank's current Country Assistance Strategy for Brazil, which emphasizes the importance of private sector-led growth, poverty reduction policies and environmental objectives.

Objectives and Methodology

1.6 The objectives and methodology of this study are as follows:

A. Assist the Brazilian Government in the design of a commercially sustainable mechanism for the electrification of dispersed rural areas. This task would consist principally of:

- characterization of the markets and determination of ability and willingness to pay by consumers;
- design of appropriate delivery options suitable for the market conditions;
- financial analysis to determine profitability of the various mechanisms to private participants;
- determination of the legal and regulatory framework within which the mechanisms could operate; and
- selection and fleshing out of the mechanism considered to have the best chance of achieving the objectives of providing affordable quality service to customers, providing fair returns to private investors, and being capable of implementation within a reasonable time period.

B. Assist the Bank's LAC region in the development of a potential Bank rural electrification operation based on the above findings. The assistance would be provided up to the preparation of the Project Concept Document (PCD) stage.

2

Market Characteristics of Unelectrified Rural Areas in Three States

2.1 The three northeastern states of Bahia, Ceará, and Minas Gerais were originally considered to take part in the ESMAP project because (1) their power companies have been fully privatized or have substantial private ownership; (2) they are committed to a public-private partnership in providing access to electricity for dispersed rural populations; (3) renewable energy technologies (RETs) had been demonstrated through a bilateral technical assistance project funded by USAID and implemented by NREL, the Centro de Pesquisas de Energia Elétrica (Brazilian Electric Research Center, or CEPEL), and utilities; (4) the amount of potential customers is substantial; and (5) natural resources—i.e., solar energy—are available all year long.[2]

Household Surveys

2.2 The analysis of the dispersed rural electricity markets in this chapter is based on three surveys performed in early 1997 by experienced local non-governmental organizations (NGOs) familiar with micro credit and rural services in general. The surveys were based on representative samples in the three states totaling more than 615 rural households, of which 150 were already connected to the grid and 465 were not. The data collected include information regarding incomes and economic activities, energy consumption patterns and expenditures, and the level of equipment in terms of electrical devices. The social and technical environment of rural households was also examined. For the State of Minas Gerais, the survey was concentrated in the Northeast, where most of the non-electrified households reside.[3]

2.3 For the characterization of the collective and productive markets, opinion leaders (political planners for such areas as electricity, health, potable water, agriculture, and education

[2] This chapter is based on Christophe de Gouvello and Marcelo Poppe, *Market of Photovoltaic for Rural Electrification in the Northeast of Brazil: States of Bahia, Ceará and Minas Gerais* (Final Report for the World Bank, supported by the French Ministry of Economy and Finance, Washington, D.C., July 1997).

[3] The questionnaire (in Portuguese) for the non-electrified population, as well as the most important survey results, appear in Annex D.

as well as federal planners for rural electrification) and technical operators (water and electricity utilities) were interviewed and available databases (IBGE,[4] Bahia Mayor Association, etc.) and literature reviewed.

Status of Conventional Rural Electrification

2.4 More than 20 million people, living in about 60,000 isolated rural communities[5] and 3 million rural estates, are not served with electricity in Brazil. A significant part of this population has no prospects of receiving electric services based on the conventional solution—i.e., extension of the distribution grid—in the foreseeable future. The reasons are the small energy consumption of rural consumers and their remoteness from existing distribution grids.

2.5 Rural electrification in Brazil is very uneven. Whereas in some states close to 100 percent of households are electrified, in other states, particularly in the Northeast and North, sometimes less than 20 percent receive electricity. In the three states of Bahia, Ceará, and Minas that are the focus of the current study, household electrification levels were 43 percent, 37 percent, and 51 percent, respectively, as of 1996 (see Table 1). In these states, as in the other states in the Northeast, rural electrification usually takes place by extending the grid. As Table 1 shows, although the transmission grid is fairly well developed, the distribution grid reaches only a few households because of the low household density in these states.

Table 1. Rural Households and Farms in Bahia, Ceará and Minas Gerais (thousands)

	Bahia	*Ceará*	*Minas Gerais*	*Total*
Area of State (1000 km^2)	567	146	588	1301
Total rural households	1088	519	931	2538
Non-electrified households	627	326	293	1246
Density (Rural Households/km^2)	1.9	3.5	1.5	1.95
Total Rural Farms	699	340	497	1536
Non-Electrified Farms	609	243	226	1078

Note: There are overlaps between the two sources of data, because a rural estate can have several households, or even no household.

Source: National Sample Survey of Households 1996, and National Survey: Agriculture Census, 1996

2.6 The starting point of any attempt to size the market for off-grid electrification is necessarily the inventory of the current and future status of conventional rural electrification. Here, two problems had to be overcome. First, in the Brazilian electrical sector, customers are classified according to their activity, based on the tariff structure. Only the customers with agricultural uses of electricity (i.e., farms) are classified as rural. All isolated households or the households located in small rural communities are classified as domestic consumers, in one class with the urban domestic customers. Therefore, the data in Table 2 are based on information about the investment in rural electrification: people living in rural areas are included in the rural

[4] *Fundação Instituto Brasileiro de Geografia e Estatística.*

[5] According to PRODEEM, the number of isolated rural communities is 100,000, resulting in a lower number of households per village.

electrification programs that cover both rural households and small farms (isolated households with at least one productive use of electricity).[6]

Table 2. Conventional Rural Electrification: Situation in 1997 and Prospects (thousand of units)

	Bahia	*Ceará*	*Minas Gerais*	*Total*
Total rural households	1,120.0	495.0	955.0	2570.0
Non-electrified communities	17.5	8.5	15.9	41.9
Non-electrified households	665.0	305.0	280.0	1250.0
Annual rhythm of grid connection	7.5	10.0	7.5	25.0
Non-electrified households in 2005	605.0	225.0	220.0	1050.0

Source: Gouvello/Poppe 1997

2.7 A second important uncertainty is related to the prospects for the progress of rural electrification following the privatization of the public utilities. In the 1990s, grid extension and connection in rural areas grew quite fast. With privatization, this process is expected to slow. It was assumed that from 1998 to 2005, between 7,500 and 10,000 consumers annually would be connected to the grid in each state, based on an annual budget for rural electrification between US$10 and US$15 million.[7] This would leave more than 1 million rural households in the three states unelectrified in 2005 (see Table 2). They can be considered the potential market for off-grid electrification.

Economic Comparisons

2.8 The effective market size for PV systems is determined by two types of analyses: (1) supply analysis, which considers the cost effectiveness of PV solutions against other technologies for rural electrification; and (2) demand analysis (or market size assessment), which compares the cost of the systems with users' willingness to pay. Each of these will be considered in turn.

Supply Options for Electrification of Off-Grid Areas

2.9 For the electrification of rural areas, several technical options exist, including the following:

- Extension of the interconnected grid;
- Installation of minigrids supplied by diesel generators, renewable energy sources, or a combination thereof; and
- Decentralized electrification based on renewables.

The cost-effectiveness of each option is determined by the distance from the existing grid, the density and number of customers, and the load factor.

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6 The survey data reported in Table 1 were published too late to take into account in Gouvello/Poppe (1997).

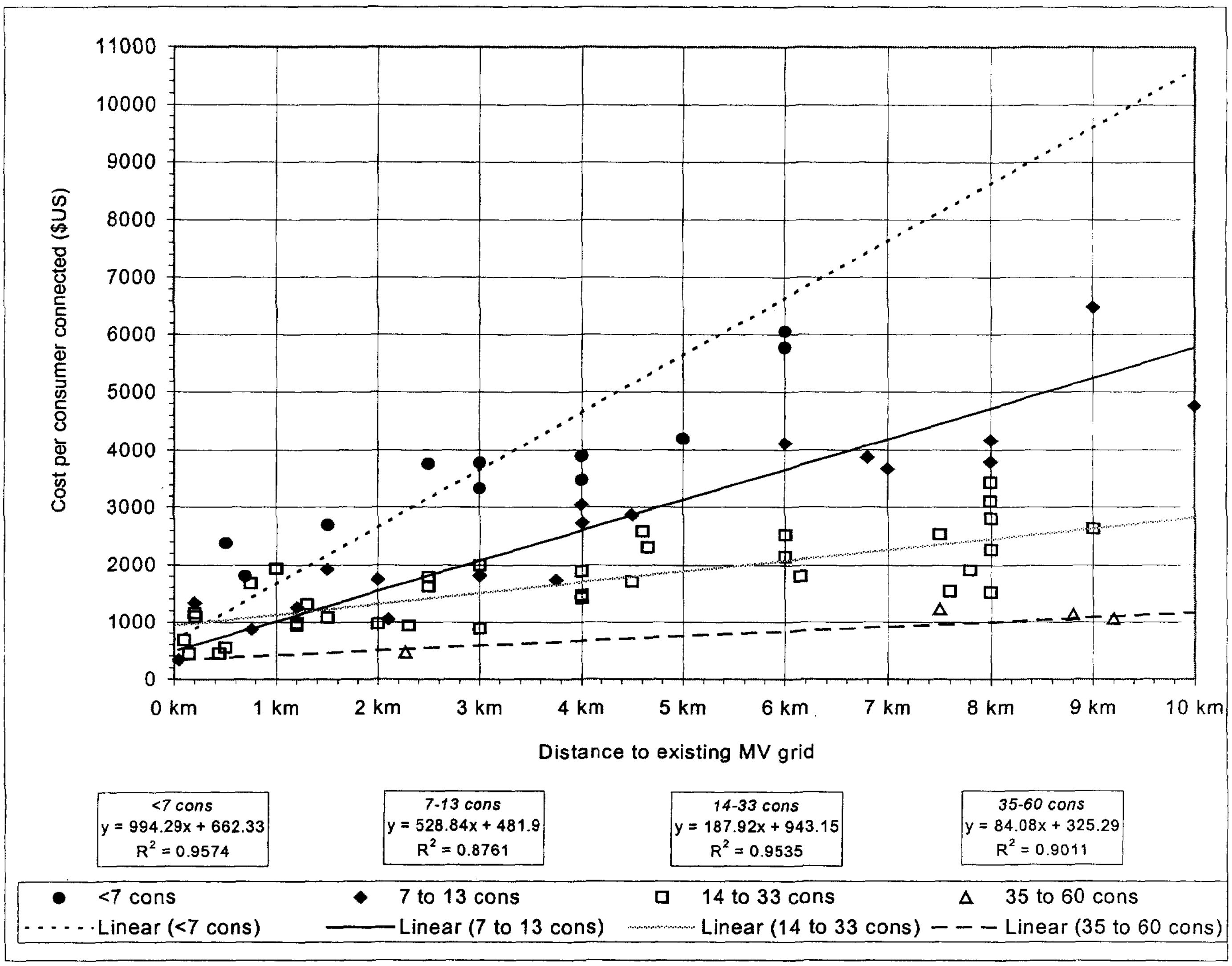
7 More-recent data from the three states indicate that the annual budget for rural electrification may be higher, resulting in a somewhat lower remaining unelectrified rural population.

Grid Extension

2.10 Figure 1 shows the effect on average investment cost per customer connected of distance to the grid and number of households in the community cluster. The analysis is based on a sample of 92 recent conventional rural electrification projects undertaken by CEMIG and indicates the following:

- Beyond about 7 kilometers from the grid, the average cost per customer exceeds US$1,000 when the number of households in the cluster is 60 or less; and
- Within 7 kilometers from the grid, a cluster of 35-60 houses may be connected for $400-900 each, the lower amount being for zero distance from the grid.

Figure 1. The Cost of Grid Connection



cons: consumers.
Source: Gouvello/Poppe 1997.

Given the low household density in the dispersed areas in the three states (see Table 1) and the households' average distance from the grid, it is clear that grid extension would be an expensive solution.[8]

Diesel Minigrid

2.11 The cost per household customer of connection to an isolated diesel minigrid depends on many factors, the most important being the number of households, household density, hours of service per day and presence of large loads (e.g., power for community centers, street lighting, power for small industries). When there is a significantly large load, a diesel minigrid may be the least-cost option, provided that diesel fuel is not excessively expensive to buy and transport to the site and that there exists adequate maintenance capability on-site. In this case, the investment cost per household, and probably also the cost per month per household, will be low because the largest burden is shouldered by the non-household application.

2.12 However, even if there is large number of agglomerated households in the site, a centralized solution such as a diesel minigrid is unlikely to be the least-cost option if the only application is residential lighting and communications. Installing a large, centralized diesel system anyway in the hope of stimulating economic activity has been shown, in decades of rural electrification worldwide, to be a bad decision in most cases.

Centralized Renewable Energy Options

2.13 Where renewable resources such as biomass (e.g., agricultural residues), hydropower, or wind are abundantly available, they should be considered for centralized installations serving households, public service centers, and productive applications. Economies of scale and low recurring costs of renewable energy systems can lower the investment cost per customer. For example, in case of Bahia, it seems that there are reasonable opportunities for windfarms in the Chapada Diamantina region in central southeast Bahia, and there are also some opportunities to produce electricity from sugar cane by cogeneration in the large plants of the sugar-and-alcohol and paper-and-cellulose industries. But these larger-scale renewable energy options are not appropriate for serving the dispersed population under consideration.

Decentralized Renewable Energy Options

2.14 These consist of individual renewable energy systems for residential use and for powering community-oriented (e.g., water pumping) and productive applications (e.g., electric fencing for livestock). The residential applications, given the economic status of households in the subject areas, are limited to lighting and home entertainment. The greatest demand is for lighting—a shift from kerosene lamps and candles to high-quality light from electric lamps.

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[8] By adopting single-phase construction as well as other cost-reducing options, the costs of grid extension could be lowered considerably. See NRECA International, *Reducing the Cost of Grid Extension for Rural Electrification* (consultant report for the Industry and Energy Department of the World Bank, Washington, D.C., 1999).

2.15 The most appropriate renewable energy technology for these individual applications is photovoltaic (PV) technology, for the simple reason that solar energy is available practically everywhere. The difference in solar intensity between ideal sites and ordinary sites is normally not significant for PV panels that derive power from diffused solar radiation and apply this power to relatively small systems. The systems range from solar pumping installations consisting of PV panels and special submersible pumps to simple solar home systems (SHSs) consisting of a 30-watt or larger PV panel, storage battery, electronic controller, and three to five lamps. These systems can provide 3-5 hours of light plus power for simple devices such as radios or small black-and-white TVs. SHS is emerging as the technology of choice in areas where households (1) are highly dispersed and have limited incomes and (2) use energy mainly (outside of cooking) for lighting.[9]

Market Size Assessment: Methodology

2.16 The effective market size is determined by comparing the cost of providing the service to the willingness of users to pay for the service. For this study, the methodology used to estimate the market size for renewable-energy electrification in the dispersed areas consisted of the following five main steps:

- Based on a systematization of the energy expenditure data collected in the field surveys in the three states, model rural households' willingness to pay for energy services.
- Define the different levels of energy services that have to be offered in order to meet the different target groups. This would be based on the analysis of survey data collected in both electrified and non-electrified areas for each of the three states.
- Segment the population of non-connected households (estimated at horizon 2005) into different groups according to the levels of energy services previously identified.
- Compare the monthly cost of the PV systems offering adequate level of service to the willingness to pay of each group, as determined by the model described before, and determine the percentage of each group that can afford the corresponding SHS on a cost-recovery basis.
- Make simulations to test the impact on market size of subsidizing the cost of equipment for those households that cannot pay for it.

Indicative Results of Market Size Assessment

The Market for Solar Home Systems

2.17 In unelectrified areas, people use substitutes for electricity—candles, kerosene, batteries—for lighting and communication purposes. Many people pay considerably more now

[9] For a more detailed analysis of the cost-effectiveness of PV solutions for household, community-oriented, and productive uses, see Gouvello/Poppe (1997).

for these inferior sources of energy than they would pay for modern sources. Based on the surveys in the three states (see Annex D), the non-electrified households belong to essentially three levels of energy expenditures (only for those energy services that could be satisfied with SHS) and corresponding incomes (see Table 3).[10] Only about 10 percent of households have monthly energy expenditures of more than US$20, not quite 25 percent spend between $10 and $20, and the majority make do with expenditures of less than $10.

Table 3. Number of Non-Electrified Households, Household Income, and Energy Expenditures

Household Type	*Income/month (US$)*	*Energy Expenditures (US$/month*)*	*Percent of Households*
I	Less than 150	Less than 10	66
II	150 to 250	Between 10 and 20	23
III	Above 250	Higher than 20	11
Total (1,050,000 households)			100

* Energy expenditures are for kerosene, candles, dry cells and battery charging. These values are levelized monthly expenses, including replacement costs.
Source: Based on surveys by Gouvello/Poppe (1997).

2.18 The sizing of the market is directly related to the segmentation of the whole residential market according to people's ability to pay. Although behavioral changes related to energy expenditure are frequently observed when households receive a grid connection, the rhythm and the nature of this change can differ greatly from one region to another. Thus, it remains hazardous to base the assessment of the SHS market on grid data. In fact, current energy expenditures offer the most reliable reference to assess the initial willingness to pay.

2.19 For this purpose, analysis focused on the relation between income and current energy expenditures (mainly kerosene and candles, car batteries, and dry-cells) and the structure of the statistical distribution of energy expenditures among the rural households of the three states. Monetary income and energy expenditures are correlated, but a range of other parameters (e.g., land-holding) also exert an influence on monetary income and thus disturb the correlation with energy expenditures.

2.20 Because the sampling was good in the three states (excellent in Bahia, good in Minas Gerais, and acceptable in Ceará), with the income distribution obtained by the survey and the income distribution for rural non-connected households established by IBGE for the year 1996 being very close (see Figures C-1 to C-3 in Annex D), it was decided to work directly with the statistical distribution of the energy expenditures. A very strong and very simple correlation between the energy expenditure level and the cumulative percentage of households according to decreasing expenditures can be observed (see Figures 2 to 4). In the following, this model is used to estimate the willingness to pay for energy services of non-connected rural households in each of the three states.

[10] Incomes and energy expenditures are correlated, but other parameters play important roles in determining the level of energy expenditures; see below.

2.21 On the basis of the energy consumption and expenditures analysis, the SHS market in each of the three states can be divided into five segments according to the needs of the different market groups (see Table 4). This segmentation can be projected onto the curve of willingness to pay, resulting for each state in the share of households belonging to a group of consumers characterized by a certain income and need for energy services (see Table 5 and Figures 2 to 4).

Table 4. Energy Services to be Provided by Each Category of Solar Home System

Level 1		*Level 2*		*Level 3*		*Level 4*		*Level 5*	
Service	*No. hours*	*Service*	*No. hours*	*Service*	*No. hours*	*Service*	*No. hours*	*Service*	*No. hours*
• 1 lamp	4	• 2 lamps	6	• 3 lamps	7	• 5 lamps	11	• 7 lamps	17
• Radio	5	• Radio	5	• Radio	4	• Radio	8	• Radio	8
				• TV or tape	3	• TV or tape	3.5	• Color TV	3.5
						• One use among :		• Parabolic antenna	3.5
						• mixer	.25	• Two uses among :	
						• fan	4	• mixer	.25
						• sewing machine	.5	• fan	4
								• sew. mach.	.5

Source: Gouvello/Poppe 1997.

Table 5. Market Segments for Solar Home Systems in the Three States (%)

State	*Group 5*	*Group 4*	*Group 3*	*Group 2*	*Group 1*
Bahia	19	38	36	8	0
Ceará	5	17	35	37	7
Minas Gerais	1	8	35	37	19
Total	9	21	35	26	8

Source: Gouvello/Poppe 1997.

Figure 2: Segmentation of the market according to the analysis of needs - Bahia 1997

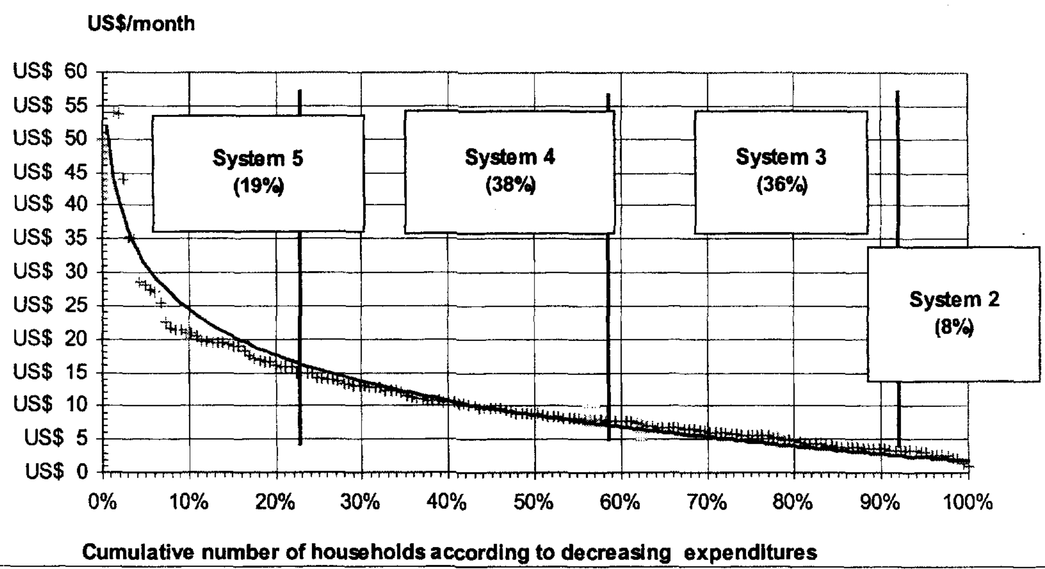


Figure 3: Segmentation of the market according to the analysis of needs - Ceara 1997

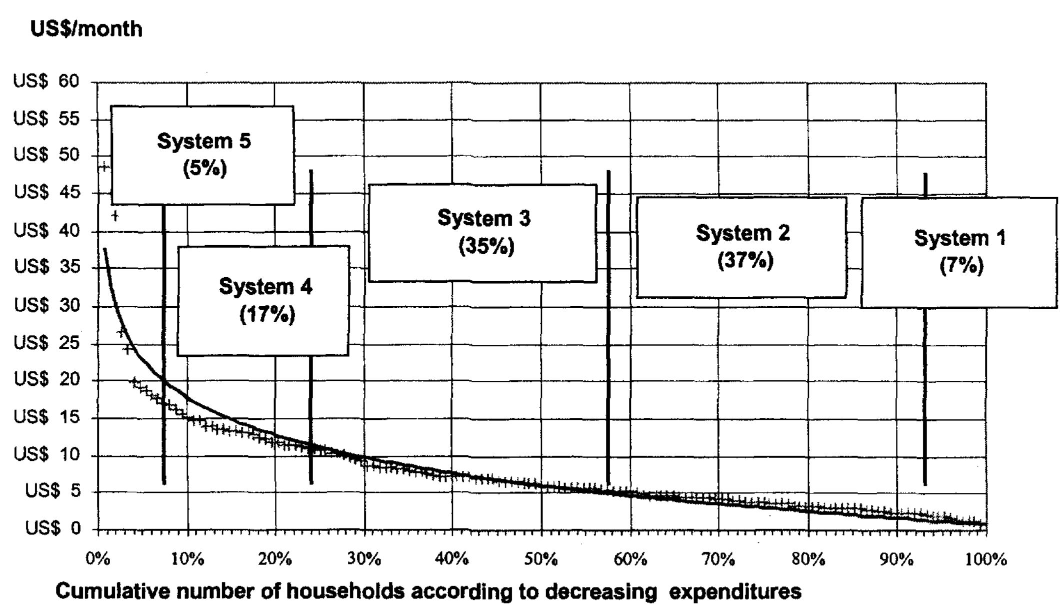
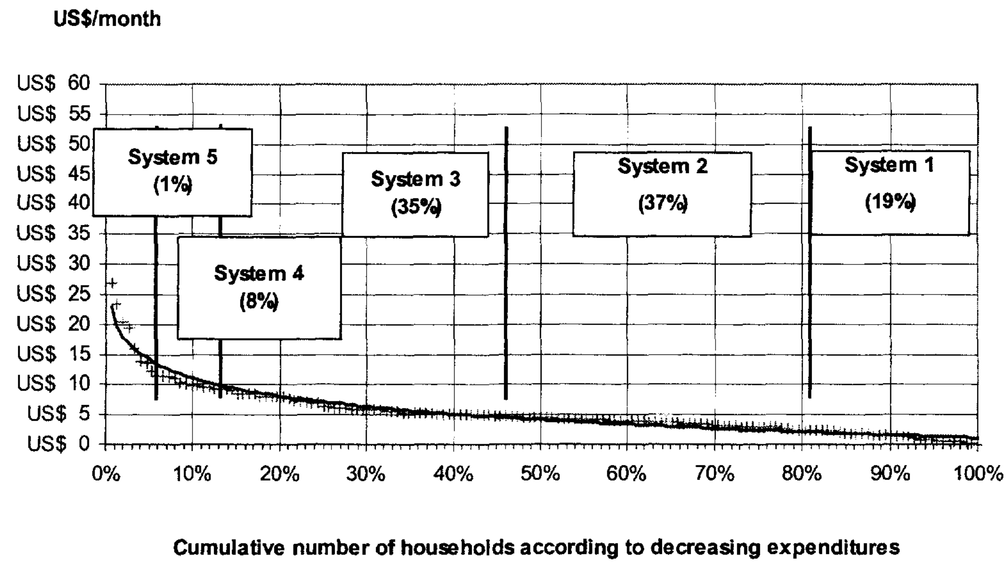


Figure 4: Segmentation of the market according to the analysis of needs - Minas Gerais 1997



2.22 One can observe that the economic limit of each segment, which is measured by the maximum expenditure in the interval, varies slightly from one state to the other. For example, the upper limit for the target group of system 4 is around US$18 per month in Bahia, and around $22 per month in Minas Gerais and Ceará. This is due to the fact that the rural prices of the energy products currently used (kerosene, LPG bottle, candle, car battery charges, dry-cells) vary significantly from one state to the other.

2.23 The next step is to compare the cost of each system with the willingness to pay of the households belonging to the target groups for which the systems have been designed. According to the result of this comparison, one can determine the fraction of each market segment for which the (levelized) cost of the proposed SHS would be lower than the current expenditures for traditional energy for light and communication. Also indicated will be the amount of subsidy that would be necessary to reach the entire target group.

2.24 Based on the analysis of the energy service levels (see Table 4), the PV systems were sized to provide a sufficient level of service for the corresponding target groups (see Table 6). The costs of each size system consist of equipment cost, spares, and cost of the delivery structure including operations and maintenance (O&M). Table 6 shows the present value of total lifecycle cost, assuming a time horizon of 15 years.

Table 6. Size, Cost and Tariffs for Solar Home Systems

	Group 1	*Group 2*	*Group 3*	*Group 4*	*Group 5*
Size (watts-peak)	15	25	70	140	280
FOB equipment cost (US$)	224	345	517	1000	2069
Present value of total cost (equipment, spares, O&M) (US$)	543	706	1068	1672	2953
Total monthly break-even fee (US$)	6.7	7.8	13.4	21.1	37.5

FOB: free-on-board.
Source: Gouvello/Poppe 1997.

2.25 As a next step, the break-even monthly tariffs were calculated for each system (see Table 6), assuming that the commercialization is made through an energy service company (ESCO), and using the present value method (a 14 percent interest rate over a period of 15 years). This monthly fee covers the cost of equipment and spare parts (for the lifetime of the equipment) and the delivery cost. [11]

2.26 The market size depends directly on the level of the tariff to be charged for each system and on the capacity to pay of the corresponding target group. Knowing the tariff to be charged, the proportion of the corresponding group able to pay can be read directly in Figures 2 to 4. If households had to pay full cost, only a fraction of those in the upper income groups (groups 3 to 5) would be able to afford solar home systems.

2.27 Simulations were then carried out, using different levels of subsidy expressed as a percentage of the free-on-board (FOB) cost of the equipment. The subsidy was calculated as a percentage of the initial cost of the system, a procedure that could be considered as a way to anticipate the decrease of future costs. In Table 7, global figures of the SHS market size for the three states are presented for zero and 30 percent subsidy, respectively. The simulations show that with a total subsidy of US$116 million, almost 50 percent more households could be electrified and almost 30 percent more power installed, increasing the net present value of the market also by almost 30 percent.

2.28 It is important to note that even with the maximum level of subsidy (100 percent of FOB equipment cost), the smaller systems 1 and 2 remain too expensive for target groups 1 and 2. In contrast, even with low or no subsidies, the market segment for bigger systems can saturate. This is mainly because the type of subsidy used softens the impact of the equipment cost but not the impact of the cost of delivering the service. This second component has a higher weight in the tariff structure of small systems than in that of bigger ones.

[11] For details of delivery costs see Chapter 4 in Gouvello/Poppe (1997), where specific distribution costs of different delivery structures are analyzed.

Table 7. Market Size for SHS, With and Without Subsidies

	Bahia	*Ceará*	*Minas Gerais*	*Total*
Number of systems:				
No subsidy	170,208	76,047	38,868	285,122
30% subsidy	258,701	107,426	59,240	425,367
Total Wp installed (million):				
No subsidy	27.8	5.1	2.1	35.0
30% subsidy	34.1	7.7	3.0	44.9
Total cost (US$ million):				
No subsidy	418	85	48	549
30% subsidy	501	123	70	694
Corresponding subsidy (US$ million)	84	22	10	116

Wp: watts-peak.
Source: Gouvello/Poppe 1997.

2.29 Thus, if state governments wanted to extend electricity service to the poorest two groups, a specific subsidy would have to be allocated to these groups, estimated to be US$1.66 million and US$4.5 million, respectively, for groups 1 and 2. This would increase the number of households covered by 57,000 and 213,000, respectively.

The PV Market for Community Applications

2.30 Many rural communities in Northeast Brazil lack basic infrastructure and/or electricity that would make provision of public services easier and less costly. Water pumping, lighting, and communication services for schools and community centers, electricity supply for health centers, and public lighting can be based on PV systems, which are the least-cost solution for electricity supply in many cases (see Gouvello/Poppe 1997). Compared to grid extension and to diesel generators for small community water pumping, economic analysis shows that the PV solution is always more cost-effective than diesel and is less costly than grid extension when the distance to the grid is greater than 0.6 kilometers (0.2 kilometers if a new MV extension is necessary).

2.31 One of the main problems faced in the study was the estimation of the number of isolated communities that are not currently supplied with electricity. In fact, the companies and agencies in charge of providing infrastructure to the rural communities catalogue only requests, which frequently results in underestimating the real needs. Nevertheless, the information obtained from the field surveys and from different Government agencies and bodies (data, literature and interviews) has allowed to estimate fairly realistic figures for collective uses in rural communities (see Table 8). Some of these uses seem to be of less importance in terms of installed power, but can be easily integrated with other more attractive services in order to provide a "multi-service station" and thus gain economies of scope.

2.32 The global figure for the physical market in the three states is about 10.2 MWp, given conservative assumptions about the rhythm of implementation, essentially by governmental agencies, during the period 1997–2005. In monetary terms, the current value of this market can be estimated at $114.5 million.

Table 8. Assessment of the Potential PV Market for Collective Uses in Bahia, Ceará, and Minas Gerais, 1997–2005

	Number of PV Systems					
Purpose	*Bahia*	*Ceará*	*Minas Gerais*	*Total*	*MWp*	*US$ million*
Water pumping	1,600	600	800	3,000	6.0	42.0
Schools	1,600	1,120	320	3,040	1.4	21.0
Health centers	480	480	480	1,440	0.6	9.0
Public lighting	8,000	8,000	4,000	20,000	2.0	40.0
Community buildings	1,600	1,600	800	4,000	0.2	2.5
Total	13,280	11,800	6,400	31,480	10.2	114.5

MWp: megawatts-peak.
Source: Gouvello/Poppe 1997.

The PV Market for Productive Uses

2.33 At the current stage of PV technology diffusion in Brazil, it is difficult to identify productive uses for which PV-based electricity is sufficiently mature. Moreover, this market depends essentially on the agricultural and breeding policies, incentives for efficiency improvements, agro-technical assistance, grants and loans policy of governments and financial institutions.[12] Nevertheless, the sector looks potentially attractive, and should be subject to more detailed studies, specially related with the improvement of productive activities in rural areas.

2.34 The market size for productive uses in the three states has been estimated only for micro-irrigation and electrical fences (see Table 9). A comparison of diesel and PV for water pumping for small scale irrigation (on about 1 hectare of land) shows that PV is always competitive over a horizon of 20 years. PV for small-scale irrigation could provide a sizable market segment. In the Northeast, goat-breeding is expanding, and the electric fences that separate animals and crops are more cost-effective than conventional wooden fences. For other potential uses, such as fruit drying or water pumping for small-fish breeding, PV may be competitive, but more detailed market characterization studies are needed.

12 See Chapter 3.

Table 9. Assessment of the Potential PV Market for the Productive Sector, 1997–2005

	Number of PV Systems					
	Bahia	Ceará	Minas Gerais	Total	MWp	$ million
Small irrigation	8,000	3,200	8,000	19,200	10.14	71.0
Electric fences	1,600	1,000	0	2,600	0.14	2.0

Source: Gouvello/Poppe 1997.

Some Conclusions

2.35 The size of the potential SHS market seems large enough in the three states to attract private sector participants to the business of electrifying dispersed areas. The key is finding the right mix of subsidized and unsubsidized market segments to make the overall package interesting. The viability of SHS dissemination depends not only on distance from the grid but also on household density. This is because installation and O&M costs are strongly affected by the degree of dispersion of the households.

2.36 Finally, it is clear that the overall cost of off-grid electrification (other than costs linked to special hardware) is highly dependent on the organization of marketing, installation, and maintenance services that could systematically cover the territory. The type of delivery mechanism chosen will determine whether sustainable operation and significant coverage can be achieved over a reasonable time period. To date, experience with delivery mechanisms exists only from small-scale pilot projects; large-scale projects, mostly in Asia, have been launched only recently and there is as yet little commercial experience to emulate (see Chapter 3). Nevertheless, there are some basic principles related to balancing costs and revenues, consistency with the sector framework, and providing adequate incentives to market participants that can be applied in selecting the best delivery mechanism for the particular context. Models for commercial dissemination of off-grid systems are emerging and, although they have been applied so far only in smaller-scale operations, they could be modified and adapted to the requirements of larger programs. These criteria and models are discussed and evaluated in Chapters 4 and 5.

3

Experience with Renewable Energy for Rural Applications

Programs and Financing Mechanisms for Renewable Energy Projects in Brazil

3.1 As mentioned in Chapter 1, the Program for Energy Development of States and Municipalities (Programa de Desenvolvimento Energético de Estados e Municípios, PRODEEM) is the only existing national mechanism aimed specifically at the implementation of renewable energy projects (REP) in rural areas.[13] Launched in 1994 by the Ministry of Mines and Energy through its National Department for Energy Development (DNDE), the objective is to improve access to modern energy by communities that are remote from conventional systems, using technically feasible, renewable energy sources that are also economically and commercially viable, politically acceptable, and environmentally sound.

3.2 The Program started by installing demonstration projects in each state, always in partnership with the local state utility. These demonstrations were followed by disseminating practical applications, integrated with other federal government programs (particularly the Community Solidarity Program) and programs of the states and municipalities. The Brazilian Electric Research Center (CEPEL) became PRODEEM's initial implementing agent, responsible for the technical analysis of approved projects and bulk purchase of equipment. These bulk purchases have resulted in substantial reduction in the prices of solar equipment in the Brazilian market.[14]

3.3 In 1998 the Ministry established inside the DNDE a Coordination unit of PRODEEM. The staff, mainly provided by Eletronorte (one of the Eletrobras generation subsidiaries), has assumed the functions previously assumed by CEPEL, which continues to provide technical expertise. As part of the restructuring project—supported by the Interamerican Development Bank's "Sustainable Markets for Sustainable Energy" (SMSE) program, USAID, and other institutions—this Unit would become a Social Organization, as part of the publication

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[13] This chapter is based on Osvaldo Soliano Pereira, *Sources of Finance and Subsidies and Agents for Dissemination of Renewable Energy* (Winrock International, Bahia, Brazil, 1997).

[14] In a competitive bid closed in May 1997, the average price of for the systems was US$8.5/Wp, for a total volume of 437 kWp. Water pumping systems were priced at US$7.7/Wp, including the pumps and all national taxes.

process stimulated by the central Government. This restructuring of PRODEEM will also result in the establishment of regional management units, currently assumed by Eletronorte and the Companhia Hidro Electrica do São Francisco (CHESF), the strengthening of state agents of PRODEEM, and the establishment of partnership with NGOs.

3.4 Although PRODEEM has four sub-programs, so far only the Social Development Sub-Program is operational. This sub-program sponsors community applications such as water pumping systems and electrification of schools, health centers, nurseries, churches, and association centers, on an equipment donation basis. However, because the number of applications has increased, the Program is now requiring higher contributions from local authorities and other ongoing programs in the candidate states. Program targets call for the installation of community applications in 5,000 villages per year, starting in 2001, leveraging up to R$50 million in state and local funds.

3.5 Other financing mechanisms that specifically support REP are the following two credit lines set up by the Banco do Nordeste do Brasil (BNB):

- The Program of Renewable Energy for the Northeast *(Programa de Energia Renovável do Nordeste*, or PROERNE). This is a credit line that finances REP for agricultural, agribusiness, industrial, and tourism purposes and the production of renewable energy equipment. It also provides institutional support and some limited resources for research and development, information dissemination, and capacity building. Its main advantage is the 40 percent rebate on total interest composed of long-term rate of interest (TJLP) plus basic spread (see Table 10). However, the program does not finance electricity equipment for residential uses. The disbursement has been hampered by several factors, inhibiting its full implementation. They include lack of capability of staff to promote and appraise specialized types projects, limited resources for information dissemination to potential borrowers and lack of interest of local branches for dealing with small loans. Another important aspect to be taken into account is the inflation culture still pervasive among farmers, inhibiting their interest in rural credit, particularly to finance relatively unknown technologies.

- Program of Support to Electricity Generation Based on Solar Energy to Small Communities for the Northeast (*Programa de Apoio à Geração de Energia Renovável para Pequenas Comunidades do Nordeste*), developed jointly with the *Fundação Teotônio Vilela* (FTV). The BNB-FTV cooperation provides financing to small local entrepreneurs in unelectrified areas for installing central stations for charging solar energy batteries as well as for installing solar home systems. These entrepreneurs typically charge R$3.00 for each battery charge, or a minimal fee of R$12.00 per month, in order to repay the loan. FTV, a non-profit organization, is responsible for (1) financing the component of the loan, also operated by BNB, covering acquisition of imported equipment and (2) for project implementation and capacity building. The financing conditions are presented in Table 10.

3.6 Aside from these two specific programs, several of BNB's more general-purpose financing programs can in principle also finance REP, particularly those for productive uses. Some of these credit lines (PROERNE, PROGER, and PROFAT Rural) are among those with the most favorable terms in the country (see Table 10). An important constraint for borrowers is the size of the required collateral, which can reach 120 to 150 percent of the loan amount. Some programs, such as the Brazilian Service of Support to Small Enterprise (SEBRAE), have created a fund to provide these collaterals.

Table 10. BNB Credit Facilities

Credit Line	*Financing Limits*	*Loan Period*	*Grace Period*	*Interest Rate*
PROERNE	Up to 100%	8 to 12 years	2 to 4 years	60% of (TJLP (1) plus 6% p.a.)
BNB/FTV	BNB: R$23200	96 months	6 months	60% of (TJLP (1) plus 6% p.a.)
	FTV: R$18000	15%: 24 months 85%: 60 months		11% p.a.
Green FNE	90 to 100% (2)	8 to 12 years	3 to 4 years	
Land	100%	7 years	2 years	12% p.a. (3)
PROGER	100%	8 years	3 years	60% of (TJLP (1) plus 6% p.a.)
PROFAT RURAL	up to 100%	6 years	2 years	TJLP plus 2 to 3% p.a.
FNE	Up to 100%	12 years	Up to 4 yeas	TJLP plus 8% p.a.

(1) Long-term interest rate: around 10% (early 1997) and 12.7% (late 1998).
(2) Small cooperatives and associations.
(3) Rebate of 50 percent of interest and principal at the moment of effective payment.
p.a. per annum.
Source: Pereira (1997).

3.7 The *Banco Nacional de Desenvolvimento Econômico e Social* (BNDES), the national development bank, has a special credit line for rural electrification, operated through the state banks. So far, the credit lines have been used for connecting productive rural areas to existing grids, using primarily low-cost electrification methods. The final borrower is the farmer and the maximum amount financed per farm is, e.g., in Bahia, R$2,500.

3.8 Eletrobrás (Centrais Elétricas Brasileiras S.A.) is responsible for managing the fund comprising the contributions of the electricity utilities to the Global Reversion Reserve (Reserva Global de Reversão, or RGR). According to Law 8631/93, Eletrobrás must reserve the RGR resources for financing the expansion and improvement of the public electric energy services, for energy conservation and for rural electrification. Law 9427/96, which created National Agency of Electric Energy (ANEEL), the Brazilian electricity sector regulatory board, stipulates that 50 percent of RGR resources must be allocated to the North, Northeast, and Middle West Regions, and 50 percent of these must be invested in rural electrification, energy efficiency, and electricity supply to low-income consumers. The total volume of resources available from RGR in 1997 was about R$1,087 million.

3.9 A special funding source directly related to the electric sector, the Conta de Consumo de Combustíveis (CCC), subsidizes the fuel costs of isolated diesel generation, mainly in the Amazon region. The annual amount is about US$300 million per year. The amount for rural electrification is probably less than one-fourth of the total because the CCC covers all big cities of the North Region (e.g., Manaus, Porto Velho, Rio Branco, Boa Vista). CCC financing has recently been made available to renewable energy projects that would displace diesel generation.

3.10 Conventional financing sources could be tapped for REP, but commercial credit lines currently have annual interest rates of over 70 percent. Rural credit lines, normally available for productive applications, have lower interest rates of 15 to 17 percent; however, the proposed projects must meet strict criteria related to the ability to produce income or employment.

3.11 Finally, rural electrification has been supported under IBRD loans for rural poverty alleviation projects to several Brazilian states, particularly in the Northeast.[15] Although decentralized sources are eligible in principle, in the vast majority of cases grid extension has been chosen (with active encouragement of the state utility), without much regard to least-cost considerations. The reasons were the lack of knowledge about renewable energy and of modules/blueprints for these installations, as well as the lack of suppliers in or close to rural areas, which would facilitate the procurement of RETs. Only recently have some NGOs started to disseminate information about rural electrification on the basis of RETs, identify projects, and help with installation and O&M.

3.12 Thus, although experience with REP on a small scale does exist in Brazil and financing is available for some applications, financing and implementation mechanisms have yet to be developed for larger-scale projects that focus on supplying basic electricity services to consumers in dispersed areas.

International Experience

3.13 Internationally, the challenge of providing energy to low-income customers in off-grid areas of developing countries in a commercially sustainable manner has been the subject of pilot activities and some modest commercial efforts in recent years. For residential lighting, SHSs—consisting of a 30-watt or larger PV panel, storage battery, electronic controller, and 4-5 lamps—have been commercially disseminated in various countries via different approaches including direct sales, leasing arrangements, and ESCO-type operations. The company Enersol has developed both leasing and ESCO operations in the Dominican Republic. Sudimara, a private company in Indonesia, has had direct sales operations in that country for many years. In Kenya, the number of SHSs sold by private dealers has exceeded the pace of grid connection in rural areas. Worldwide, the experience so far with customer acceptance of SHSs has been uniformly good: the systems work reliably and users value the benefits.

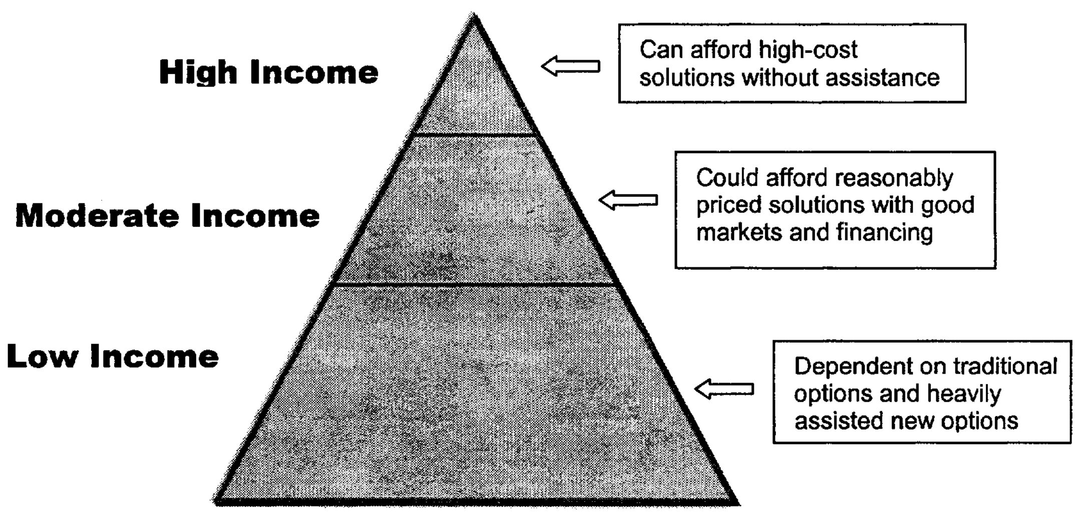
3.14 Typically, dealers have reached only a very small number of rural customers, i.e., those rich enough to pay cash for the SHSs (see Figure 5). In order to reach a larger percentage of

[15] One example is the Bahia Rural Poverty Alleviation Project. World Bank Staff Appraisal Report No. 14390, Washington, D.C., 1995.

the dispersed population, dealers need to provide financing along with the installation. Financing at relatively low interest rates and extended terms is rarely available, and here the World Bank has become active. It has recently financed a number of renewable energy projects, including the following:

- The Bank's first stand-alone PV project, a US$111 million Indonesia Solar Home Systems Project financed by a US$20 million IBRD loan and a US$20 million Global Environment Facility (GEF) grant, the balance coming from local funds; and
- A US$55 million Sri Lanka Energy Services Delivery Project financed by US$24 million in IDA funds and US$5.5 million from GEF.

Figure 5. Energy Solutions for Rural Populations



3.15 The Indonesia project aims to provide solar home systems (averaging 50 watts per unit) to about 200,000 homes in rural areas through a commercial approach. The Sri Lanka project has as one of its components a SHS commercial dissemination program targeting 20,000 homes. Under negotiation is a US$187 million project in Argentina that aims to supply solar electricity to about 100,000 homes and public centers in 10 provinces.[16] Finally, under preparation is a US$400 million renewable energy project in China, one component of which is the provision of SHSs to some 200,000 nomadic tribes people in the Western part of the country.

3.16 In the projects described above, the commercial dissemination approach has been of two types: the competing-dealerships or vendor-based approach and the concession or regulated-market approach. In the former mechanism, vendors of equipment or services freely compete and provide financing to customers. In the latter approach, the right to provide services to a whole area, such as a province, is awarded to a single concessionaire or permissionaire who asks for the least

[16] In Argentina, the Government extends subsidies to the poorest part of the population so that also they can obtain basic electricity services.

subsidy. It is too early to tell which approach under what conditions is the optimum for any particular market. Chapter 4 discusses the considerations involved.

4

Considerations in Selecting Commercial Delivery Mechanisms

4.1 In Brazil, state-owned distribution utilities have historically borne the responsibility for extending electricity services to rural areas.[17] Although as a monopolistic concessionaire they could have been obligated by the regulatory authority to provide rural electrification services, regulatory authorities usually did not require this. Rather, the concessionaire often carried out electrification under political pressure.

4.2 With the implementation of power sector reform, concessions will generally be held by majority investor-owned companies; however, in a few states, the state will retain majority ownership. States are selling some or all of the ownership shares under competitive solicitations and are anxious to maximize the proceeds from the sale, and to improve the technical and commercial performance of the utility. Bidders are foreign utilities or utility affiliates as well as financial and other institutions. The bidding criterion is usually the price offered for the concession. Any intentions the bidders may have regarding rural electrification have not, thus far, entered into the award process.

4.3 Under recent legislation, Brazil's distribution concessionaires are required to electrify rural areas only up to their "limits of investment."[18] In general, these limits spare utilities from having to extend services to remote rural areas without government financial assistance. Although the overall regulatory framework is established, many details have yet to be filled in, including those that determine the extent of concessionaires' responsibility for rural electrification.

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[17] This chapter is based on Keith Kozloff, *Deploying Renewable Energy Systems for Rural Electrification in Brazil: An Evaluation of Alternative Mechanisms* (prepared by Hagler Bailly Services, Inc., for USAID Office of Energy, Environment, and Technology, Washington, D.C., 1997).

[18] In the case of Bahia, the limit for COELBA (Companhia de Eletricidade do Bahia) investment is R$254 per new connection for small users. This amount corresponds to the net present value of the accumulated minimum bill over the lifetime of the grid.

4.4 International experience suggests that a variety of delivery mechanisms exist that may or may not be appropriate under specific Brazilian circumstances. In the remainder of this chapter, they will be discussed in terms of how they fit in with the evolving policy and regulatory framework, the market barriers they are supposed to overcome, and how they fare in general terms with respect to economic sustainability and feasibility of implementation. In Chapter 5, the advantages and disadvantages of alternative commercial delivery mechanisms for solar home systems will be discussed in more detail.

Policy Framework

4.5 On the basis of existing and proposed power sector policies in Brazil, several legally recognized mechanisms could be employed to provide off-grid electricity services. One such mechanism is the *primary distribution concession*. Under both existing and proposed power sector policies, electricity distribution concessionaires have the primary right to distribute, and responsibility for distributing, electricity to all customers within their concession areas. Existing concessions cover the whole country and entire states, and existing concessionaires could implement off-grid electrification.

4.6 Under an existing loan of the World Bank to Brazil,[19] Coopers & Lybrand developed proposals for power sector reform. In a supplemental study (see Annex C for a summary), the consultant proposed different approaches for supporting isolated systems that specify and limit cross-subsidies between customer classes. The development of isolated systems would be supported by a subsidy from customers of the host interconnected system. Regulatory approval would be required for subsidies that deviate from cost-reflective charges to customer classes. The ability of concessionaires to impose customer class cross-subsidies will be constrained not only by regulation, but also by the threat of losing non-captive customers when open access becomes available to smaller customers in the future. For isolated systems without an associated interconnected system (as in the states of Roraima, Para, and Amapa), Coopers & Lybrand propose creating a "National System of Subsidy for Isolated Systems" (SNSI) that would be funded by a wires charge collected nationally by concessionaires.

4.7 Another mechanism for providing off-grid electricity services is a *subconcession*. As an alternative to providing services directly, new private concessionaires may elect to competitively issue a subconcession for providing off-grid services to specified areas. The concessionaire is essentially ceding part of its service area, but retains the ultimate responsibility for providing the service. The subconcessionaire has the same rights and responsibilities as the concessionaire within the limits of the subconcession, which must be approved by the granting authority. The concept of a subconcession was introduced in Brazil in February 1995 by Law 8987, but no implementing legislation has been established since then.

4.8 Another legal mechanism to consider is the *permit*. In contrast to concessions, permits have not generally been used in Brazil for public services (that is, monopolies) such as

[19] The loan was originally to Petrobras and was restructured to add a component under the responsibility of the Secretariat of Energy for energy sector reform. The Secretariat of Energy empowered Eletrobras as its administrative arm for the power sector reform component.

conventional electricity distribution. Permits have, however, been granted to rural electric cooperatives to extend the grid to areas not yet supplied by the concessionaire. With respect to implementing the permit approach, either ANEEL or a state regulatory authority would award the permit. Potential permissionaires could include the primary concessionaire, concessionaires from other states, rural cooperatives, and joint ventures between renewable energy developers and utilities, NGOs, and other institutions. A permissionaire's rights to serve a given customer do not appear to be subordinate to those of a concessionaire. Potential conflicts between the two would thus be on economic rather than legal grounds. In the past, permissionaires were not regulated by the former National Department of Water and Electric Energy (DNAEE). Now ANEEL is producing an implementing regulation to control their tariffs.

4.9 Concessionaires are currently the primary entities possessing explicit rights and obligations for providing retail electricity services in Brazil. However, in the future, distribution concessionaires could face competition in serving deregulated customers from independent power producers (IPPs) and other electricity retailers. IPPs can sell electricity to concessionaires, permissionaires, and certain types of retail consumers (including consumers who can demonstrate to the granting authority that the local concessionaire did not provide electricity within 180 days of the request). However, as a practical matter, those consumers would not constitute a well defined market. Finally, because distribution and retail activities are being unbundled, independent electricity retailers could theoretically provide off-grid services. This possibility, however, seems even less likely than for IPPs.

4.10 Aside from these regulated-market options, there is a legal gap through which open-market participants can (and do) provide these services. Marketing solar home systems (SHSs) or other renewable energy systems to individual off-grid customers can already now be undertaken without formal government sanction. Under open-market mechanisms, individual entrepreneurs do not need any government or utility approvals to market SHSs, battery charging services, or other independent renewable energy services. Once energy is generated for resale (for example, in a village mini-grid), however, approval is required from the local utility that has the monopoly of distribution, unless a permit has been awarded by the regulatory agency.

4.11 Moreover, the approvals needed for a subconcessionaire or permissionaire to develop off-grid renewable energy services for isolated communities or homes are not all defined in existing laws or regulations. The authority to implement such mechanisms could be derived from laws covering similar activities, including those addressing small hydroelectric generation and rural electric cooperatives. The lack of clarity on what approvals are required to undertake specific projects, however, may not be a serious roadblock. Given the prevailing political philosophy of promoting private investment and deregulation, the lack of regulation is more likely to be interpreted as a go-ahead than a prohibition. It is important to note, however, that unless a permission has been previously awarded, any initiative to supply electricity to a group of consumers inside the area of an existing concessionaire would face strong opposition from this utility, resulting in disputes to be resolved by the regulatory agency.

4.12 Granting a subconcession or permit for the purpose of serving off-grid rural households and communities with independent power sources has not been explicitly contemplated in the emerging new regulatory framework. One key issue is which agency will bear the responsibility for regulating these various entities. Until recently, DNAEE was responsible for approving new generation projects; now, all of the functions of DNAEE have been assumed by ANEEL. In the coming years, it is expected that the regulatory authority will be decentralized, with some of the responsibilities of ANEEL gradually devolving to those states technically and administratively capable of assuming them. State regulatory agencies would likely first be granted authority over quality of service issues and later authority for licensing.

Market Barriers

4.13 On the consumer side, the principal barrier to wider use of most off-grid renewable energy systems is their high front-end cost. In Brazil, for example, the price of a 50-Wp SHS is about US$900. Where financing mechanisms are not available, as is often the case in dispersed rural areas, the market for such systems will be a very limited one. The second principal barrier is lack of information on the characteristics and benefits of renewable energy options, which in turn inhibits consumer acceptance of the technologies. Many households surveyed in rural areas of Brazil, for example, thought that SHSs can only deliver lighting. Others thought that receiving these decentralized options would prevent them from obtaining the more desirable grid connection in the future.

4.14 For potential private investors, the main barriers include (1) insufficient information to make investment decisions about such things as market size and characteristics, the costs of operation and maintenance of systems in dispersed and difficult terrain, adequacy of the proposed tariffs, and potential difficulty in tariff collection; and (2) the need for substantial investment resources at the front end, due to the high-capital-cost/low-recurring-cost nature of renewable energy investments. These capital resources are at risk from the potential for consumer default or termination of service.

4.15 From a public policy viewpoint, decisions to adopt a conventional approach to electrification on the basis of cost considerations alone often fail to account for important externalities. The air quality and health benefits of replacing kerosene, candles, or diesel-charged batteries with PV systems are often not accounted for in rural energy investment decisions, nor are the cost-reduction benefits expected to accrue to future users that result from early adoption of the alternative technology, stimulating movement along the learning curve.

Criteria for Commercial Delivery Mechanisms

4.16 The ideal mechanisms for deploying renewable energy systems to serve Brazil's rural areas should overcome the above-named critical barriers. They should also fulfill certain criteria relating to the policy objectives of economic sustainability and feasibility of implementation. The mechanisms should

- result in a balance between costs and revenues,
- be consistent with the incentives of potential market entrants,
- result in the least-cost mix of technologies being adopted to serve various applications,

- relative to the status quo, accelerate the rate of extending service to target markets,
- ensure that the service provided meets at least the basic needs of customers,
- be consistent with the emerging legal framework for the power sector in Brazil, and
- allow implementation within a reasonable period of time.

Economic Sustainability

4.17 Different ways of bringing costs and revenues into balance favor some deployment mechanisms over others. For example, competition and its efficiency benefits can be stimulated in several ways. One is to allow multiple firms to offer services in the same geographic area in an open-market context. In a regulated-market context, one approach is to subdivide the unelectrified portion of a state into two or more service territories, ensure that different entities are operating under a subconcession or permission arrangement in each region, and evaluate their cost and quality of service performance over a specified time period, after which poor performers are weeded out. Another approach is to award multiple concessions covering the same service area and let consumers choose their supplier.[20]

4.18 Regulated-market mechanisms that require competitive bidding to select among potential service providers have greater potential for minimizing the cost of service than those that do not. However, the actual efficiency gains from competition over sole-source awards may be less than what is theoretically possible. Even when bids are evaluated primarily on the sole criterion of price, the actual process of evaluating and awarding bids may be quite different from how it appears on paper.

4.19 Whether economic sustainability is more effectively promoted by stimulating competition or economies of scale depends on local market characteristics. For example, stimulating competition by subdividing the unelectrified area of a state is worth sacrificing potential efficiency gains from a larger scale of operation only if the market is sufficiently attractive to entice several competitors to enter it. The most effective approach for a given setting may need to be determined empirically.

4.20 Finally, sustainability can be promoted by allowing service levels to change over time. For example, SHSs may initially be the least-cost option for isolated households. When the aggregate level of electricity demand within a given area crosses a certain threshold, however, mini-grids become more cost-effective than individual household systems. At an even higher demand threshold, grid extension may become cost-effective.

4.21 In addition to competition and economies of scale, "economies of scope" can also help bring costs and revenues into balance. This refers to the ability to make use of under-used economic resources (e.g., labor, office space, vehicles, revenue collection systems) that might

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20 For example, this approach is used in New England for rural telecommunications services, according to Richard Cowart, Commissioner of the Vermont Public Service Board. It is also generally used in the telecommunications sector in Brazil.

already be available to organizations delivering products or services other than electricity to rural areas.

Feasibility of Implementation

4.22 In order to overcome the barriers to the more rapid diffusion of renewable energy systems in rural areas, it must be feasible to implement the chosen deployment mechanism within a reasonable period of time, regardless of how well it fulfills the long-term objectives of economic sustainability. The mechanism should ensure that a local entity is available to deliver the full range of services (marketing, design, installation, O&M, financing, revenue collection). The key objectives may include the following:

- Relative to the status quo, the mechanism should accelerate the rate of extending electricity services to villages, farms, and households.
- Providers should have incentives for delivering high-quality service (or a range of quality).
- The mechanism should facilitate a complete marketing/value chain (from equipment supply to after-sales service).
- Service providers should have the flexibility to market related products and services.

5

Comparison of Alternative Delivery Mechanisms

5.1 This chapter summarizes the advantages and disadvantages of possible alternative mechanisms for the commercial dissemination of solar home systems.[21] Based on conceptual models rather than actual examples, it discusses options for both open and regulated markets.

Open-market Options

Independent Dealers

5.2 The simplest open-market approach is for individual small entrepreneurs to market SHSs and related services at the local level, as they are already doing in several countries (e.g., Dominican Republic, Kenya, India, Sri Lanka, Zimbabwe) and to some extent in Brazil. Independent dealers have been successful in marketing other relatively expensive technologies in rural Brazil, for example, satellite TV dishes ("parabolicas").[22]

5.3 With respect to sustainability objectives, individual dealers have the following characteristics:

- *Advantages*
  - Vigorous competition among dealers for serving the same area would promote efficiency, thereby reducing costs.
  - Organizationally, this is an easy mechanism to implement, requiring no approvals to offer service, or, subsequently, need for regulation.
  - Local firms that already provide other services to rural residents may be interested in expanding their business to include SHSs. Firms that are already marketing

[21] This chapter is based on Kozloff (1997).

[22] Interestingly, although *parabolicas* involve more sophisticated technology than SHS, they have been packaged for easy installation.

products and services in an area may see a business opportunity in providing services related to renewable energy.[23]

- *Disadvantages*
  - The scale of operation of individual entrepreneurs may be too small to be efficient with respect to market entry, capital, and O&M costs. The small size of individual dealers means they do not have the resources to make a sufficiently large number of sales to achieve scale economies.
  - The cost of capital may be high due to various project risks.
  - Individual dealers may not have the capital or access to capital to offer customer financing.
  - Service providers in open-market systems may promote systems that only relatively well-off rural households can afford with cash sales (cream-skimming) thus limiting penetration.

Franchise Networks

5.4 In this variation of the open-market approach, individual entrepreneurs are organized through a parent organization similar to the way that fast food franchises are organized.[24] As an example of this concept, Golden Genesis in Brazil sells franchises for solar battery charging stations through a nonprofit foundation,[25] which prepares entrepreneurs through training programs and by qualifying them for loans.

5.5 With respect to economic sustainability, franchises have the following characteristics:

- *Advantage*
  - Relative to independent dealers, a franchise system has the potential to achieve scale economies from bulk equipment purchases and marketing, standardization of service and training, brand recognition, and potential for reduced financing transaction costs.
- *Disadvantage*
  - Because of the emphasis on standardization, individual franchises may not be able to adjust services to meet a range of local needs.

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23 If marketing and servicing SHSs is the sole source of income for a rural entrepreneur, the corresponding market territory would need to be larger than if SHSs were marketed along with other products requiring periodic services.

24 Hence the nickname "MacSolar" for the Solar Development Corporation (SDC). The concept was developed jointly by the IBRD, IFC, and and some U.S. charitable organizations. Currently, managers for the SDC are being recruited and capitalization has started.

25 FTV; see Chapter 3.

Rural Energy Service Companies

5.6 Rural energy service companies (ESCOs) might address a range of consumptive end uses (i.e., lighting, television, cooking) and productive end uses (irrigation water pumping, sewing machine operation) by offering some combination of energy supply and efficient end-use equipment. The equipment delivery, after-sales service, and consumer financing mechanisms that need to be established for SHSs may also be appropriate for extension to a broader range of energy services. ESCOs might provide a full range of products, from solar lanterns to small water pumping systems. Alternatively, they might sell end-use services directly by combining PV systems or battery charging with highly efficient lights and televisions, water purification systems, and so on. For off-grid areas, there is obviously complementarity between marketing PV systems and electricity-using appliances.

5.7 With respect to economic sustainability, ESCOs have the following characteristics:

- *Advantage:*
  - Economies of scope could be attained by combining complementary energy supply and end-use services. For example, it may be more cost-effective to support local technicians trained to service several types of equipment rather than just one.
- *Disadvantage:*
  - More-efficient end-use technologies usually involve higher costs up front.

Regulated-market Options

Concession

5.8 Several characteristics of the concession model affect how well the objective of economic sustainability is met. The following advantages and disadvantages apply:

- *Advantages*
  - Because concessionaires' service territory is the entire state or large parts of one state, they have access to a large unelectrified market. This gives them the ability to spread any up-front development costs over a large customer base and to purchase equipment in large volumes.
  - Although concessionaires could conceivably face competition for providing services to off-grid areas, non-concessionaire providers might not be able to use customer cross-subsidies and access the proposed national subsidy fund (SNSI; see Chapter 4). In addition, the concessionaires' name recognition suggests that they would face little actual competition for this market.
  - Electricity distribution concessionaires already have local offices in many communities and have a better understanding of local customers in their rural area than many other potential service providers. They may also have existing

employees who are surplus (at least part of the time) and could be reallocated to providing O&M or other local services.

- Concessionaires have the opportunity to blend risks and returns from serving off-grid customers with risks and returns from their grid-connected services.
- To the extent that their cost of capital is affected by market risk, concessionaires are likely to face low costs of capital relative to entities that face more market risk.
- If demand grows sufficiently after SHSs are installed to warrant grid extension, the systems can be re-deployed elsewhere with little down-time or lost investment.

- *Disadvantage*
  - Once the concessionaire is selected, the government loses leverage. The cost, quality, and pace of service provision depend on commitment by the concessionaire, although some means of regulatory intervention can be provided. The regulatory authority might pressure the concessionaire into improving service provision or use economic incentives to do so (by adopting performance-based regulation, for example). In general, however, the implicit competition created by the threat of revoking the concession is weak compared to robust market competition.

5.9 With respect to implementation, the concession model has the following characteristics:

- *Advantages*
  - Once the primary concession is granted, no additional regulatory approval is required in order for the concessionaire to provide off-grid services.
  - Because different electricity services (such as grid extension, mini-grids, and off-grid services) could all be provided by the same entity, coordination among them would be relatively easy. This is especially important in states such as Minas Gerais, which do not have large, well-defined, unconnected regions.
  - Because of its established presence, the concessionaire already knows many characteristics of rural markets.
- *Disadvantages*
  - State-owned utility concessionaires have not provided adequate service to rural areas up to this point, and private concessionaires are likely to be even less interested in doing so. So far, winning bidders for distribution concessions in Brazil have not included companies that have demonstrated interest in providing off-grid services (such as Idaho Power).
  - If the primary concessionaire does not have sufficient in-house expertise to provide off-grid services, it will need to either acquire this expertise itself or subcontract for these services. The choice of subcontractor is critical because, so far, the new owners of privatized Brazilian utilities have not had extensive prior experience with using renewables for off-grid electrification.

Subconcession

5.10 With respect to economic sustainability, the subconcession model has some characteristics in common with the concession model.

- *Advantages*
    - Like the concessionaire, the subconcessionaire has the opportunity to minimize costs of service through bulk purchase of equipment and spreading market entry costs over a large area.
    - Competitive bidding is required to issue a subconcession, although afterwards the subconcessionaire faces little or no competition.
    - Because they operate under the same regulatory rules as concessionaires, subconcessionaires would likely have the ability to use customer cross-subsidies and benefit from the proposed subsidy system (SNSI) to fund off-grid services.
    - Because the subconcessionaire acts at the behest of the concessionaire, coordination between grid extension and providing off-grid services would be relatively easy, assuming they have a sound contractual relationship.

5.11 With respect to implementation, the subconcession model has the following characteristics:

- *Advantages*
    - Given the reluctance of the state and federal governments to impose additional conditions on the sale of state utilities, addressing the rural electrification issue after privatization may be more realistic than *a priori* imposing requirements in the concession contract.
    - Subconcessionaires can be selected from among bidders according to their technical qualifications to supply renewable energy services to off-grid markets.
- *Disadvantages*
    - Subconcessions can only be created by a new concessionaire, which may not want to relinquish certain service areas even though the areas may currently be considered liabilities. This could prolong uneconomic grid extension.
    - Issuing a subconcession does not absolve the concessionaire of the ultimate responsibility for providing service to what may be seen as an unprofitable market.
    - The regulatory restrictions on tariffs and services imposed on the concessionaire also apply to the subconcessionaire.

Permit

5.12 The permit or license approach has the following characteristics:

- *Advantages*
  - Like the other two regulated-market models, the permissionaire could have access to a sufficiently large market to achieve some scale economies through bulk equipment purchases and spreading market entry costs among a large number of customers.
  - A permit may be awarded without requiring payment by the permissionaire.
  - The approval process for implementation is less formal. A key difference between permissionaires and subconcessionaires is the approvals required. The former only requires the approval of the government granting authority, whereas the latter requires the approval of both the granting authority and the concessionaire.
- *Disadvantages*
  - Unlike the concessionaire or subconcessionaire, the permissionaire does not necessarily have access either to customer cross-subsidies or to the proposed SNSI.[26]
  - Because there is no contractual relationship between a permissionaire providing off-grid electricity services and the concessionaire, the permissionaire faces potential competition from the concessionaire in the event that demand increases sufficiently to justify grid extension by the concessionaire to villages served by the permissionaire. This risk could raise the cost of capital to the permissionaire.
  - Concessionaires may take legal action to oppose the opening of a permit, especially without receiving compensation for loss of a portion of their service area that they have previously purchased the right to serve. This means that the regulator must be willing to engage in a conflict with the concessionaire over this issue.
  - Competitive bidding is not required in awarding a permit. Neither, however, is it prohibited. Moreover, if the off-grid market is not sufficiently lucrative to attract the concessionaire, the lack of competitive bidding may be a minor shortcoming.
  - If a concessionaire wanted to extend the grid to a village currently being served by a permissionaire, the permissionaire would have to receive compensation if its permit were revoked by the granting authority.
  - The granting authority must pro-actively make the permit compatible with the existing primary distribution concession in the state.

Conclusions

5.13 Open-market approaches differ from regulated-market approaches in several respects. A key advantage of open-market over regulated-market options is the potential efficiency gains induced through competition and consumer choice. This advantage is realized,

[26] It is very likely, though, that permissionaires would have access to the SNSI.

however, only if the market is sufficiently lucrative to attract multiple competitors. To date, rural energy markets in Brazil have not been characterized by vigorous competition.

5.14 A key advantage of regulated-market over open-market options is the potential for scale economies and other efficiency gains that accrue from access to a large market. This advantage is realized, however, only if entrants to the regulated market are granted some form of exclusive access. Because there is no legal restriction in Brazil on marketing renewable energy systems for individual applications, at best, entrants can be granted exclusive access to below-market sources of finance and to community applications that provide a base-level demand to help defray market entry costs. Regulated-market approaches rely on an explicit rural electrification policy and the presence of a regulatory body capable of enforcing it.

5.15 In the near term, in view of their relative advantages and disadvantages, the regulated-market approaches appear to have greater potential than open-market approaches for achieving both economic sustainability and a certain scale and speed of electrification of dispersed areas in Brazil. Nonetheless, both open- and regulated-market approaches would require an entity qualified to deliver services at the local level. Moreover, it may be desirable or even necessary to combine elements of open-market mechanisms with whichever regulated-market approach is most appropriate for a given state.

5.16 Among the three regulated-market approaches, the concession option appears the most likely to be economically sustainable, given the advantages listed for it. In terms of implementation, however, the permit or subconcession options are more likely to attract interested and qualified participants.

6

A Proposed Investment Project

6.1 Due to the nature of the market, an investment project that aims to provide electricity services to consumers in off-grid areas of Northeast Brazil can only be carried out through a public/private sector partnership. Based on the results of analyses in the previous chapters, forging such a partnership requires that the project:

- design customer cost-recovery schemes that take into account the willingness and ability to pay of customers in different market segments;
- give the private participant an opportunity to develop a scale of operation that can spread market entry costs over a large area;
- provide financing to offset the high front-end investment costs for renewable energy installations; and
- provide subsidy over a limited time period to help develop lower-income market segments.

6.2 The financing could be provided through a World Bank loan to the Government of Brazil. In addition, GEF grants could be blended with the Bank loan to (1) provide hardware "buy down" of eligible installations and (2) shoulder the costs of activities needed to reduce market barriers, such as market characterization studies that can provide more detailed information to prospective investors. This blending of Bank loan with GEF grants has been done before for similar projects in other countries involving the commercialization of environmentally benign energy technologies (see Chapter 3). The project investment costs would then be covered by the Bank loan, GEF grant, private participant financing, customer down payments and other Government funds intended for rural energy development (e.g., PRODEEM and BNDES/BNB funds).

6.3 Considering these factors, the project outlined below proposes the following mechanism:

- If the exisiting concessionaire is not interested in implementing the project, subconcessions or permission areas would be awarded to private implementers through competitive bidding. The customers in the service area would consist of households, public service centers, and productive applications. The number of customers in the awarded area should be such that it permits a significant scale of operation.

- Public service centers and community-oriented applications would be funded in part by PRODEEM and other existing programs and would represent a "guaranteed market" for the winning service provider. Productive applications, such as micro-irrigation, would be financed by a combination of owner equity and BNDES/BNB loan programs. Household customers would be required to make a down payment and pay a monthly tariff to cover the lifecycle cost of the installation, replacements, and maintenance over 15 years or the agreed-upon concession period. That portion of the household market whose willingness to pay is marginally lower than the installation cost may be eligible for a GEF grant, the magnitude of which will depend on the calculated "incremental costs" (see Annex E). The GEF grant in all cases would decline to zero over the project implementation period.

Project Description Summary

6.4 The project would be focused on three states in the Northeast: Bahia, Ceará, and Minas Gerais. These states are considered for initiating project preparation because:

- their power companies have been fully privatized or have substantial private ownership,
- they are committed to the project concept of a public-private partnership in providing access to electricity for dispersed rural populations,
- market information is available,
- the number of potential customers is substantial, and
- natural resources (i.e., solar energy) are available all year long.

The target coverage over a five-year period is shown in Table 11.

Table 11. Project Components

Market Segment	*Number of Installations*	*Average Unit Cost (US$)*	*Total Cost (US$ million)*
Households (SHS)			
50W	66,000	647	42.7
100W	7,100	1,446	10.3
Public Service/Community Applications	1,169	6,700-7,200	8.1
Productive Applications	565	5,000-13,500	3.8

Source: World Bank Staff.

Description of Components

Solar Home Systems

6.5 This component will provide financing and transitory subsidies to household customers to offset the initially higher life cycle cost of shifting from traditional fuel use to higher-quality SHSs. Up to 66,000 households in dispersed rural areas will be provided with a SHS under this component. For GEF-eligible clients, a grant will be provided in a declining schedule that becomes zero after five years (see Table 12). In addition, up to 7,000 less-poor households will be provided larger systems but will not be eligible for GEF grants.

Table 12. SHS Tariffs and GEF Grant

SHS Size	Suggested GEF Grant, $/unit	Net Financial Tariff, $/month
50W	140 at Year 1, declining to zero at Year 5	15.4
100W and above	zero	28.9

Source: World Bank Staff.

6.6 The GEF grant for 50-watt systems is designed to equalize the lifetime costs of SHSs with current expenditures for traditional lighting fuels. The low population density, the difficulty of terrain, and the relative novelty of the technology necessitate a relatively significant GEF involvement up front (compared to other rural electrification projects) in order to gain critical mass, in particular during the first three years—the period required for full-scale deployment of installation, operation, and maintenance facilities.

6.7 At the end of five years, it is expected that cost reductions—particularly in operations and maintenance, and through volume purchases achieved through substantial expansion of the consumer base—will obviate the need for GEF grants. Considering other possibilities for cost reductions (such as a global drop in PV prices in the next five years and/or reduction of taxes and duties), it is expected that system lifecycle costs will have dropped by at least the full initial amount of the GEF grant per unit. At that time, the band of households with the capability and willingness to pay for the lower-cost systems will have expanded. The market within these three states could then be served at full cost recovery without GEF subsidy.

6.8 The project does not include service to very poor households who are not expected to develop into a viable market in the medium term. However, it is not ruled out that a small part of this segment could be served, based on the lifeline criteria applied to consumers served by conventional distribution networks. This could happen if (1) Federal or State current funds are available to pay for part of the capital cost of SHSs and (2) the users can afford to pay at least the recurring costs of operation.

Public Services

6.9 The project component on renewable energy technologies (RETs) for public centers and community applications will essentially involve the provision of financial and technical support to PRODEEM activities in the three states. PRODEEM is currently active in 25 states and has spent about R$19 million between 1994 and 1998 on municipal level projects using RETs for public lighting, community water supply, and other applications (see Chapter 3). The budget for PRODEEM in 1999 was R$30 million from federal funds only with some in-kind contributions from states and municipalities for installation and maintenance of the PV systems.

6.10 One of PRODEEM's main achievements is the sensitization of rural communities to new technologies, which helps pave the way for private initiatives. The envisioned cost sharing of subprojects for community-oriented applications under the Bank project is as follows: World Bank Loan, 30 percent; Federal, State, and/or Municipal Governments, 70 percent.

Productive Uses

6.11 Government programs promoting the use of RETs for productive applications exist but need to be revitalized. The specific applications range from PV-powered micro-irrigation systems to the use of wind/diesel hybrids to power ice-making for fish preservation.

6.12 Brazilian development banks such as BNDES and BNB currently have lines of credit available for financing energy-related projects as well as special credit lines for rural electrification (see Chapter 3). Although none of these is specifically directed at RETs, discussions with BNDES officials indicate the availability of these instruments for productive uses of RETs as well. At the regional level, BNB has financing windows for RET applications, such as PROERNE. These funds have not been utilized so far to any significant extent for reasons including lack of information dissemination, lack of interest of local branches in making small loans, and lack of assistance for identifying project opportunities and assessing project viability.

6.13 The proposed Bank project will help these BNDES/BNB initiatives in the rural areas to improve their profile by providing resources for demonstrations and expert assistance in pipeline-filling activities. The envisioned cost-sharing of productive-use sub-projects is as follows: BNDES/BNB, 50 percent; user equity, 20 percent; and concessionaire financing, 30 percent.

6.14 The most effective way to improve potential users' perception of the benefits of the applications is to actually construct working demonstrations of selected applications where they can be conveniently viewed by prospective clients and the general public. At least one demonstration installation in each state will be built. It is proposed to finance the demonstration of productive uses of RETs with $0.9 million, of which $0.7 million would be a GEF grant. A qualified consulting company would be commissioned to identify demonstration systems and then to design, construct, and (initially) operate them. The private party cofinancing the systems would have the responsibility of carrying out the public demonstrations after the initial consultant-managed period.

Technical Assistance for Reducing Market Information Barriers

6.15 This component is aimed at:

- improving the availability and dissemination of information on market characteristics and private investment opportunities;
- promoting public awareness of the costs and benefits of RETs, and thereby conditioning the market for the concessionaires;
- improving the availability of various direct-current (dc) appliances to SHS users;
- establishing standards, testing, and certification programs for PV equipment and appliances; and
- conducting feasibility studies to help small rural businesses develop viable projects employing RETs.

In addition, the project will support the establishment of demonstration systems for productive applications of RETs in the three states. This will stimulate the identification, design, and execution of private subprojects to be financed mainly by existing loan windows in the development banks.

Technical Assistance for Capacity/Institution Building

6.16 This component involves three components:

1. Core support to a project management unit (PMU) at the central government level to enable it to
    - administer the project overall and provide technical assistance to staff of the state regulatory agencies and to the concessionaires during project implementation;
    - contract and coordinate execution of all technical assistance components of the Bank project;
    - design and execute an effective monitoring and evaluation program to assess performance of the project; and
    - prepare a strategy for replication of the project in other states;
2. Strengthening of the regulatory process for dispersed area markets, including the provision of training opportunities on the technical, economic, and financial aspects of SHSs and other RETs to staff of state and federal regulatory bodies, concessionaires, and state secretariats of energy; and
3. Support to PRODEEM project management to improve its technical capability in project identification, appraisal, execution and monitoring, and assist in its development of a long-term program with clear geographic and technological priorities.

Summary of Financing Requirements

6.17 The project would cost $113 million. Table 13 breaks this figure down into project components and their potential funding sources.

Table 13. Project Costs and Sources of Financing (US$ million)

Component	*Source of financing* *World Bank*	*Local Sources*	*GEF*	*Total*
Solar systems for homes, community centers, and productive uses	53.0	41.0	8.6	102.6
TA to reduce information barriers	0	1.0	3.6	4.6
Programs for project administration and capacity building	0	2.0	3.8	5.8
Total	53.0	44.0	16.0	113.0

TA: technical assistance.
Note: Includes taxes, contingencies, and interest during construction.
Source: World Bank Staff.

Possibilities for World Bank Financing

6.18 As described earlier, the proposed project is in essence a conventional investment project that would test commercial delivery mechanisms for off-grid rural electrification on the basis of renewable energy technologies in three states of Brazil.

6.19 There is an advantage to working with three states rather than one: it allows for the comparison of various delivery mechanisms and business plans and selection of the most successful ones for future replication. Small-scale SHS pilot projects have already been implemented in the three selected states, and their technical viability has been demonstrated. The proposed project is a full-size commercial demonstration project, where the concept to be tested is the participation of the private sector in delivering commercial services based on renewable energy, using tariff or leasing mechanisms. Project size in each selected state has been estimated, based on the size of the unserved population and feasible market penetration and scale economies in service delivery, both in capital and operational cost.

6.20 An alternative would be to design not one conventional investment project but a series of projects in the form of an "adaptable program loan" (APL). An APL would provide flexibility for adapting lessons learned during Phase 1 implementation. Whereas the first phase would concentrate on SHS and public-service applications in three states, subsequent phases would expand investment to other states and other technologies (see Box 1 on the following page). This would support the Brazilian Government's long-term goal of implementing RET-based electrification programs in all Brazilian states.

Box 1. Indicative APL Program Phases

Phase 1, 1999-2003

1. Test implementation arrangements, marketing options, and regulatory mechanisms for SHSs for electrification of dispersed rural population in three Northeast states.
2. Pilot RET hybrids for minigrids to test technical, operational, and marketing options.
3. Market and resource studies for Phase 2 states.

Project cost: US$110 million; Bank loan: US$55 million; GEF grant: US$12-18 million.

Phase 2, 2002-2006

1. Expand coverage in Phase 1 states.
2. Apply selected SHS implementation mechanisms to additional three states in the Northeast/Amazon region.
3. Apply RET hybrids to selected sites in the six states.
4. Test financing options for productive sector RET applications.
5. Market/resource studies for Phase 3 states.

Project cost: TBD*; Bank loan: TBD.

Phase 3, 2004-2008

1. Expand coverage in Phase 2 states.
2. Apply SHS marketing mechanisms and RET hybrid systems to selected states in other regions.
3. Implement financing mechanisms for productive sector applications in selected states.

Project cost: TBD; Bank loan: TBD.

Estimated total program cost: US$250-US$300 million.

*To be determined.

7

Summary and Conclusions

7.1 The challenge of sustainably providing electricity services to millions of households in off-grid rural areas of Brazil is a huge one. Renewable energy systems (RESs) are the least-cost supply option for most of these markets because of their modular and decentralized nature. Several formidable market barriers, including the high front-end cost of RESs, need to be addressed before widespread use can occur. New mechanisms for commercial dissemination of RESs, characterized by maximum participation by the private sector, need to be devised. There is evidence of growing private sector interest in large-scale deployment of renewable energy equipment and services. The utilities in two of the three target states appear poised to participate in new initiatives to electrify dispersed areas in their territories. Additionally, in all states there are potential permissionaires, such as rural electrification cooperatives and rural credit cooperatives, that could become suppliers of cost-effective and sustainable energy services.

7.2 Several modalities for private sector provision of electricity services to off-grid areas are possible under the existing and emerging policy framework for the power sector in Brazil. Among the regulated-market options are the concession (jointly for grid and off-grid electrification), subconcession, and permit mechanisms. The open-market options include independent dealerships, franchises, and rural ESCOs. In general, the open-market options have a better chance of achieving efficiency gains through competition. However, the regulated-market options have the advantage of potential economies of scale and other efficiency gains that accrue from access to a large market. Considering the particular characteristics of the dispersed area markets in the three states, especially the low density of population, the present study considers the regulated-market approaches as having a better chance of attracting private sector participants than the open-market options, as well as being more feasible to implement and achieve a certain coverage within a reasonable period of time. However, regulatory action needs to be taken to provide flexibility for the delivery of electricity services to rural consumers and incentives for the private sector to actively pursue this market.

7.3 Chapter 6 described the implementation plan for a proposed project, as well as the potential cost sharing of the principal participants: the Federal, state and municipal governments; the private service provider; and the consumers. Absent more-detailed market characterization studies and more-rigorous cash flow analyses, it is difficult to determine the real profitability and commercial attractiveness of the scheme to prospective private investors.

7.4 Potential service providers are uncertain as to how to measure the financial viability of off-grid electricity services. The threshold test of financial viability is different for concessionaires than for other unregulated providers.[27] Under current regulations, distribution concessionaires have an exclusive market with a per-household limit of investment for extending service to unconnected households. At the same time, they face tariff structures that do not allow them to recover the full costs of service from low-income and rural households, other than through cross-subsidies with larger, urban residential consumers. Regulations currently do not cover the provision of off-grid services. For distribution concessionaires, a threshold test for viability is that the following conditions are satisfied: (1) the net capital investment (total system cost minus subsidies) does not exceed the investment that would otherwise be made to extend the grid, and (2) project revenue is adequate to cover all O&M expenses and provides a return equivalent to what would have been received from grid extension. Clearly, project proponents must first prepare detailed business plans that will ideally provide results sufficiently attractive to prospective participants.

7.5 Bank officials who have reviewed the proposed project are concerned about the high project risks, particularly the ex-ante attractiveness of the project to the private sector, future cost reductions, and willingness to pay of poor rural customers. To reduce these risks, it was suggested that the interested concessionaires prepare their own business plans and that additional site and household surveys be done during project preparation. Close participation of NGOs and affected communities should be considered as well. In order to reduce risk in general, the scope of the proposal could be scaled down, taking care not to weaken sustainability characteristics. The reduced activity would become a pilot project to test the viability of the proposed implementation mechanisms. In any case, there is no doubt that Bank financing and technical involvement in a project that would benefit off-grid populations can catalyze the growth of private sector interest in these areas and stimulate market growth.

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27 An initial financial assessment of the project was done in George Sterzinger, *Off-Grid Solar Home Systems: A Financial and Regulatory Analysis* (Winrock International, Bahia, Brazil, 1997). See Annex F.

Annex A

Workshop Program: Rio de Janeiro, 7 July 1997

BRASIL: PROPOSTA DO PROJETO DE ENERGIAS RENOVÁVEIS PARA ELETRIFICAÇÃO RURAL NO NORDESTE
Workshop de Conceituação do Projeto
Rio de Janeiro, 7 de Julho de 1997
Programa

9:00	Abertura:	Eugenio Mancini - DNDE Jeff Seabright - USAID Philipe Delleurs - Ministério Francês de Finanças
9:20	Objetivos do Workshop: Luis M. Vaca-Soto - Banco Mundial	

Seção 1: Definição do Mercado 9:30-10:40

9:30	Observações iniciais: Anke Sofia Meyer - Banco Mundial
9:40-10:30	Mercado Residencial, de Usos Comunitários e Produtivos para Aplicação de Energia Solar Fotovoltaica - Christophe de Gouvello e Marcelo Poppe - CIRED/WBI
10:30-10:40	Perguntas e Respostas

Seção 2: Políticas e Recurso 11:00-12:40

11:00	Observações iniciais: Bill Howley - Winrock International
11:05-11:20	Recurso Solar: Dave Renne - NREL
11:20-11:35	Recurso Eólico: Dennis Elliot - NREL
11:35-11:45	Perguntas e Respostas
11:45-12:05	Financiamento e Sistemas de Comercialização Existentes: Osvaldo Soliano Pereira - Winrock International
12:05-12:25	Aspectos Políticos e Institucionais: Keith Kozloff - Hagler Bailly
12:25-12:40	Perguntas e Respostas

Painel de Discussões 14:00-16:00 PM

Moderador:	Ernesto Terrado - Banco Mundial
Panelistas:	Eugenio Mancini - DNDE Aldo Fabris - Secretaria de Energia, Argentina Eraldo Tinoco - Secretaria de Energia, Transportes e Comunicações, Bahia Richard Hansen - Enersol Demonstenes da Silva - DNAEE Jaime Millan - IDB Jose Carvalho Neto - CEMIG Roberto Coelho da Silva - CONBRAC Roberto Gentil - COELCE

Annex B

List of Consultant Reports Prepared for the ESMAP Project

Elliot, Dennis. 1997. *An Evaluation of Wind Resource Information in Brazil and a Proposed Plan for Wind Energy Resource Assessment of Brazil.* Golden, Colorado: National Renewable Energy Laboratory.

de Gouvello, Christophe, and Marcelo Poppe. July 1997. *Market of Photovoltaic for Rural Electrification in the Northeast of Brazil: States of Bahia, Ceará and Minas Gerais.* Final Report for the World Bank, supported by the French Ministry of Economy and Finance. Washington, D.C.

Instituto de Desenvolvimento Sustentável e Energias Renováveis (IDER). July 1996. *Brazil Renewable Energy Program: Potential of Sustainable Projects; Preparatory Study for Supply of Rural Energy Using Renewable Energy.* Prepared for Winrock International by IDER. Fortaleza, Brazil.

Kozloff, Keith. 1997. *Deploying Renewable Energy Systems for Rural Electrification in Brazil: An Evaluation of Alternative Mechanisms.* Prepared by Hagler Bailly Services, Inc. for USAID Office of Energy, Environment, and Technology. Washington, D.C.

———. 1998. *Deploying Renewable Energy Systems in Rural Brazil: Further Analysis of Alternative Mechanisms and Sustainability Issues.* Prepared by Hagler Bailly Services, Inc., for the USAID Office of Energy, Environment, and Technology. Washington, D.C.

Pereira, Osvaldo Soliano. 1997. *Sources of Finance and Subsidies and Agents for Dissemination of Renewable Energy.* Bahia, Brazil: Winrock International.

Renne, Dave et al. 1997. *An Evaluation of Solar Resource Information in Brazil.* Golden, Colorado: National Renewable Energy Laboratory.

Sterzinger, George. 1997. *Off-Grid Solar Home Systems: A Financial and Regulatory Analysis.* Bahia, Brazil: Winrock International.

Annex C

Excerpts from Kozloff (1998)

Subsidies for Off-Grid and Grid-Connected Customers

The financial package that will be offered through the World Bank loan is likely to provide some degree of subsidy to low income people in dispersed areas.[28] For example, the Bank might provide full investment subsidy for SHS, with participating households required to pay monthly amounts for recurring costs (O&M, replacements) of $2-3 per month.

At the same time, the World Bank wants to ensure that its involvement in the rural electricity market does not distort electricity service choices. In particular, it would like to avoid subsidies for off-grid service options that exceed those subsidies currently available for grid power, especially if off-grid subsidies would cause customers to deviate from choosing the least cost option for providing electricity service from society's perspective. Stated another way, the Bank wants to know the minimum charge to consumers to avoid biasing their decisions.

To compare subsidies for grid and off-grid electricity services poses challenges in terms of both analytic framework and data. First, a uniform analytic framework does not exist for comparing the relative subsidies associated with renewable versus nonrenewable energy service options. (How to compare such subsidies has been a controversial topic in the United States.) In this case, for example, subsidies might be compared on a per kWh or per household basis. Moreover, with both grid extension and SHS, there are two cost categories that may be subsidized — the initial capital costs of SHS and the various recurring costs. Ideally, a comparison of subsidies between grid extension and SHS should include both capital and recurring cost categories.

Second, estimating subsidies based on these frameworks requires accurate information on the actual costs of providing grid power to customers that could otherwise receive power from off-grid sources. With adequate data, the subsidy comparison might cover only some cost categories.

The capital costs for extending grid power per rural household varies widely according to their distance to the grid and load density. Without grid extension cost data for each household, an accurate assessment of investment subsidies is not possible. For example, CEMIG's cost for grid extension are R$4,500/km. of monophase line and R$7,500/km. of three phase line, both low voltage. There are areas in Minas Gerais where load density is less than one customer per kilometer of line and other areas where there are several customers per kilometer.

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28 Excerpted from Keith Kozloff, *Deploying Renewable Energy Systems in Rural Brazil: Further Analysis of Alternative Mechanisms and Sustainability Issues,* prepared by Hagler Bailly Services, Inc., for the USAID Office of Energy, Environment, and Technology (Washington, D.C., 1998).

A limited comparison of the subsidies for grid power versus SHS can be made by excluding the capital costs of grid extension and SHS. This may be a reasonable simplification. First, SHS are presumably installed only in households where they are a more cost effective option than grid extension (from the utility's accounting perspective).

Second, individual customers themselves typically do not pay the up-front capital costs of extending the grid nor the up-front capital costs of SHS. In the case of grid extension by a privatized utility, the capital costs are paid by the utility only up to its "limits of investment" with the remainder paid by the government. In the case of SHS, to date capital costs have often been split among the utility, government and international donors. In the case of CEMIG (state majority-owned), the allocation of capital costs will be the same for both conventional grid extension and SHS, 64% to CEMIG and 36% to local government.[29]

Exhibit 2: Tariff Policy

The rural tariffs currently in effect in each state were established under the previous regulatory body, DNAEE. How and when these will be modified by ANEEL is not yet known for certain, although the government is considering recommendations on tariff structure made by Coopers & Lybrand.

During a meeting between the project team and ANEEL, the agency stated its initial position on funding for rural electrification to be that customer cross-subsidies should not be used and that such obligations are better funded through tax revenues. The agency is concerned that cross-subsidies could jeopardize the financial viability of utilities, especially once retail competition is established.

In contrast, MME maintains that at least a portion of rural electrification funding should come through cross-subsidies. According to an MME official, ANEEL could establish a range of acceptable tariffs for grid extension. Subsidies should be available up to some value based on the average cost of service. This official maintains that rural customers should be cross-subsidized up to some limit. (In states without a utility regulator, the limits of cross-subsidies would be set by ANEEL presumably in coordination with the state. The level at which these limits are set can become political as states with large rural populations may want relatively high cross-subsidies while shifting the responsibility for raising urban rates to the national government.

Leaving aside subsidies for initial capital costs, monthly tariffs provide a partial indication of subsidy levels. With respect to power from the grid, some electricity tariffs in Brazil do not reflect the full costs of providing service. Low-income and rural users receive tariff subsidies. In some cases, the CCC and RGR have been used to subsidize generation costs of conventional electrification or isolated grids (See Kozloff, 1997).

According to *current* tariff structures, distribution utilities are restricted in how much they can charge low-income and rural customers. These tariffs limit cost recovery for grid-based

[29] Personal communication, Antonia Sonia Cardoso Diniz, CEMIG, April 17, 1998.

electricity. In contrast, tariffs are not specified for off-grid rural electrification, thus, concessionaires and other parties could presumably compete on an equal footing with respect to what they can charge for the services.

Future tariff structures are likely to become more cost-based. If the Government of Brazil adopts the recommendations by its consultants on power sector restructuring,[30] cross-subsidies within and across customer classes will be limited by regulation (Because the cost of serving rural areas is generally higher, however, rural subsidies/kWh may remain greater than urban subsidies for low income consumers.) See Exhibit 2.

Although tariffs in Ceará are slightly higher than in Minas Gerais and Bahia, the tariffs in the three states are close enough to compare them to charges for off-grid services. The following residential analysis use CEMIG's tariff structure. (See Exhibit 3) Tariff tables for the other two states are included as Appendix A.2 in (Kozloff 1998).

Exhibit 3: 1998 Partial Tariff Schedule for CEMIG

Customer Class	Consumption (kWh/month)	Charge (R$/kWh unless otherwise indicated)
Low income residential	less than 30	0.04454
"	31-100	0.07634
"	101-180	0.11452
"	Minimum monthly charge	R$1.34/month
Average monthly consumption of CEMIG's low income customers	159	R$16.39/month
Normal residential		0.12724
Ave. mo.consumption of CEMIG's normal residential customers	270	R$28.16/month
Rural residential		0.07447
Average monthly consumption of CEMIG's rural customers	310	R$23.09/month
Rural electric cooperative (wholesale tariff)		0.05261

To fairly compare subsidies, the levels of service provided need to be normalized. Subsidies for grid power are estimated below in two ways — in terms of R$ per household and R$ per kWh consumed. Both estimates are instructive because grid-connected low-income households typically use much more power than SHS users.

Exhibit 4 displays implicit subsidies for different customer classes for grid power, using the following simplifying assumptions:

- The tariffs charged to normal residential customers reflect the true costs of service. (In reality, there is probably some cross-subsidy embedded in their rates.)

[30] Coopers & Lybrand, 1997.

- The costs of service/kWh are the same for normal residential, low income, and rural customer classes. (In reality class load shape differences affect costs/kWh.)

Given these assumptions, the tariff subsidies are calculated as the difference between normal residential rates and the other two rates (for the low income and rural classes). For example, at their average monthly consumption level of 159/kWh, low income customers pay about R$4/month less than normal residential customers at the same consumption level (R$20.23 - R$16.39). Rural customers (probably mostly farmers) pay only R$11.84 for 159 kWh/month, R$8.39 less than the charge for normal residential customers for the same level of consumption.

Exhibit 4: Implicit Subsidies by Customer Class and Type of Service for Grid Power

Customer Class	R$/household/month Subsidy	R$/kWh Subsidy
Low income@5 kWh/month	R$0 (minimum charge applies)	R$0.00/kWh
Low income@30 kWh/month	R$2.48/month	R$0.083/kWh
Low income@159 kWh/month	R$4.16/month	R$ 0.024/kWh
Rural @159 kWh/month	R$8.39/month	R$0.05277/kWh

Low income customers make a minimum monthly payment for grid power. Recognizing the limitations of the above analysis, this observation suggests that low levels of consumption (comparable to consumption from SHS users) have zero or low subsidies on a per household and per kWh basis.

If R$0 subsidy for recurring costs is the standard to be met by SHS programs, some but not all past SHS programs have met this test. Because SHS services are unregulated, there is much more variation in how recipients of SHS are charged than with grid power. To date, most recipients have been charged some monthly fees, but have not made down payments. Each program incurs costs and charges recipients somewhat differently. Exhibit 5 shows a range of representative values from some recent projects.

Clearly, monthly payments of R$0 represent a subsidy that distorts the market. On the other hand, monthly payments of R$12.60 recovers not only O&M costs, but also some of the initial capital costs.

Exhibit 5: Representative SHS Payments[31]

SHS Project	Down payment	Monthly Payments
CEMIG pilot SHS program 50Wp SHS	R$0	R$ 4/month
CEMIG pilot SHSprogram 100Wp SHS	R$0	R$ 8/month
IDER pilot SHS program 50Wp SHS	R$48	R$12.60 for 48 mos.
COELCE pilot SHS project	R$0	R$0

[31] See subsequent sections of Kozloff (1998) for a description of these programs.

In summary, both the initial capital cost of grid extension and SHS are typically 100% subsidized. The monetary value of the capital subsidy for grid extension is at least as large as that for SHS where least cost principles are followed. Existing subsidy levels embedded in monthly payments grid power and SHS can and do affect a household's preferences for type of service. The current tariff structure affects the incentives of unconnected low-income households regarding their choice of grid or off-grid service as well as their consumption levels (assuming potential customers are aware of service options). From the perspective of an unconnected low income household, paying R$1.34 for usage up to 30 kWh/month is much more attractive than, for example, paying R$4 for at most a tenth of that service level.

Update on Off-Grid Renewable Energy Activities and Delineation of Potential Service Areas in Minas Gerais, Ceara and Bahia

MINAS GERAIS

Update on Off-Grid Renewable Energy Activities

CEMIG:

As part of its overall rural electrification effort, CEMIG is implementing or participating in three programs that include off-grid renewable power generation. In the "Luz de Minas" program, CEMIG is ramping up a pilot SHS project. CEMIG promotes SHS as "pre-electrification" to avoid giving the impression that participants will never receive the grid.[32] The current plan is to install 4,700 SHS. CEMIG retains ownership over the module and controllers. Once the grid comes, the SHS will be moved to another site. According to its shareholder contract, CEMIG will allocate a minimum of 5% of its profits to rural electrification (In some past years, CEMIG's contribution to these projects has been somewhat higher.). Depending on profits in a given year, the annual allocation is expected to be $20-$40 million, which is projected to allow all households to be served within five years.[33]

In the first phase of the pilot program, 14 SHS were installed in the villages of Icara and Esadá Mão Tortá, both northeast of Diamantina. To identify appropriate project sites, CEMIG worked with EMATER, which has a network of offices throughout the state. The two villages are about 20 km. from the grid.
As part of this study, a visit was made to Icara. Of the 14 SHS installed, 9 are doubles and 5 are singles (see Exhibit 6). Each tube serves two rooms by being located on the underside of the roof above the wall separating them. Typically, one CFL is outside the front door and the other is in the kitchen.

32 As another part of its pre-electrification effort, CEMIG is trying to improve the load shape such as through providing power for irrigation. A higher load factor could justify grid extension. Households as far as 10 km. from the grid can request service.

33 Outside observers asserted that the new private owners of CEMIG, AES and Southern Company, have reduced plans for rural electrification because of the inability to fully recover this investment.

Exhibit 6: Characteristics of SHS Pilot Project

Characteristics	Single System	Double System
Peak watts	50	100
Number of 20 W Fluorescent tubes	1	2
Number of 9 W CFLs	2	2
Inverter for radio	1	1
Socket for transistorized TV		1
Monthly payments by users	R$4	R$8
Capital cost of each SHS to CEMIG	R$1,200	R$1,500

The systems were installed by CEMIG technicians and a local electrician, who maintains them and also collects payments from participants. The monthly payments are intended to cover maintenance and parts replacement costs only. The electrician sends monthly reports to CEMIG which pays him R$100/month for his services. He spends about 52 hours/month cleaning terminals and panels, taking measurements, and changing lamp positions. Users clean the panels (about twice a week depending on season), but the electrician does not think they would be able to clean battery terminals. Only one battery, which was defective, has been replaced to date. The rest are expected to last 3-4 years.

Clearly, this small pilot is not at a large enough scale to be sustainable. For example, the electrician is paid more than is received. The electrician now spends about 3.7 hours per household per month and receives payment equivalent to R$7 per household per month. To make SHS servicing a full time occupation would require at least 50 households in an area that could be visited in a day. Servicing costs are increased due to the time it takes for the electrician to reach the village — three hours on foot and 40 minutes on bicycle — due to the poor roads and rough terrain. Every three months, the electrician also travels to Belo Horizonte to report to CEMIG. The labor time of CEMIG staff in marketing, installing, and monitoring this project has not been assessed. Several visits were required before the villagers agreed to participate in the program. The electrician received training during the 3 week installation period.

Interest in the first phase project has spread through word of mouth; CEMIG has not solicited additional participants. Since the SHS were installed two years ago, 14 more families in the village have requested receiving a SHS and 54 families in the immediate area have made this request as well.

Some lessons from the first phase include:

- establishing trust with local people is very important and takes time;
- identification and training of a local technician is critical; and
- interest in receiving a SHS spreads significantly by word of mouth.

CEMIG is currently expanding to a second phase of its Luz de Minas program that will reach 500 households. This phase will use a turnkey approach. The winners of a competitive solicitation held in late 1997 will be responsible for installing, training, and servicing systems, with CEMIG in a supervisory role. CEMIG will also coordinate the training for local installers of community systems and SHS. Fees will be collected either by the municipality or a village leader. In the second phase, monthly charges are still under discussion, but are expected to remain around the levels in the first phase -- R$4/month for a single system and R$8/month for a double system (One CEMIG technician thinks that higher charges would prevent some people from participating.) The municipal government will pay 36% of the capital costs and CEMIG will pay 64%. The municipalities may support their share through local taxes.

In addition to Luz de Minas, CEMIG participates in a program with PRODEEM, called the Communal Centers Electrification Program. In 1997, 37 systems were installed in 13 schools, 3 churches, and 13 pumping systems for a total of 30.3 kW. CEMIG is currently setting up a maintenance procedure for this program. To provide local technicians with expertise for installing and maintaining PV systems, CEMIG has established a PV training center in its school for professional improvement (EFAP), located in Sete Lagoas about 70 km from Belo Horizonte. CEMIG has an additional 30 kW of PV systems to be installed through this program in 1998.

CEMIG also operates a School Electrification Program with grant support from the Minas State Government and PRODEEM. This program targets 1,500 rural schools using PV systems to be installed between 1997 and 2000. Partners in this effort include CEMIG, the Government of Minas Gerais (Secretariat of Education, Secretariat of Planning, and Secretariat of Water, Mineral, and Energy Resources), and PRODEEM. The objective is to supply electricity and potable water to schools through PV-powered pumping systems, although in some cases potable water will also be supplied to the community. The program is intended to promote tele-education in rural schools, as well as to allow adult night classes for an otherwise illiterate population. In the first phase, 100 systems are being installed. PRODEEM's contribution to the first phase is R$497,000.

CEMIG had also installed 75 PV systems in 1995-96 in northern Minas Gerais, including 20 in rural schools, 42 in low-income rural homes, and 13 in other buildings (health clinics, churches and community centers). The homes were served by 100 Wp systems (plus a load controller and two batteries) for lights and a radio. The schools received 500 Wp systems (with controller, inverter, and 10 batteries) for up to 8 fluorescent lamps, TV, VCR, and satellite dish antenna. The project's goal is to demonstrate the feasibility of PV technology, using equipment in several municipalities in the northern sector of the state. Participants in this project include CEMIG, CEPEL, US Department of Energy, and National Renewable Energy Laboratory.

While CEMIG has responsibility for implementing these programs, the role of the Secretariat of Mines and Energy is to establish state policy regarding rural electrification. To date, the relationship between the Secretariat of Mines and Energy and CEMIG has been quite close. The Secretariat is developing general procedures to assure that the objectives of its policies and the PV programs will be met. However, its staffing in this area is currently limited.

Regarding alternative mechanisms for off-grid renewable energy deployment, CEMIG prefers to retain primary responsibility and is opposed to either a permissionaire or subconcessionaire approach. A subcontractor approach, however, would be considered. CEMIG cited the need to establish trust among rural people as a reason why it should maintain control over off-grid electrification rather than adopting a free market approach.

OTHER OFF-GRID PROJECTS:

A consortium consisting of PRODEEM, the government-owned water company COPASA, Fundacao Banco do Brasil, and Fundacao Teotonio Vilela (FTV) will provide off-grid electricity services to 20,000 households. FTV is providing a warranty. See Exhibit 7.

Exhibit 7: Community PV Program in Minas Gerais

Partner	PV Application	Contribution
Copasa	water pumping for drinking and food production for local consumption[34]	R$9 million (grant) and installation and maintenance services for other community applications
Fundacao Banco do Brasil	Social applications (such as refrigeration)	R$ 4.5 million (grant)
PRODEEM	Social applications	R$1.5 million (grant)
FTV	SHS for 20,000 households	R$12 million from BNDES (line of credit, capital to be recovered from users) and maintenance services

The consortium has targeted 430 communities, the first phase of which is to serve 96 communities. To be selected, the communities need to have a minimum of 30 households in an area with a 2 km. radius, the closest of which is 3 km. from the grid. The consortium is in the process of resolving financing issues. In the next phase of this program, a turnkey approach will be used.

Delineation of Potential Service Areas

In Minas Gerais, markets for SHS and other off-grid renewable power sources may be more usefully identified by their geographic, demographic, and economic characteristics than by delineating contiguous regions as a package to attract investment. The grid in Minas Gerais is relatively well-developed, reducing the potential size of contiguous SHS service areas. In contrast to Bahia and Ceará, large contiguous unelectrified regions do not exist in Minas Gerais.

CEMIG has maintained its stated goal of 100% electrification. CEMIGs current transmission expansion plans through 2008 for its north and east regions are shown in four maps in Appendix A2 in Kozloff 1998. These plans indicate transmission line extensions down to the 34.5 kV level as well as planned substations and other equipment.[35]

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[34] COPASA initially wanted CEMIG to provide electricity for its water services, but CEMIG did not agree to provide these services. Consequently, COPASA stepped in.

[35] Companhia Energética de Minas Gerais (CEMIG). Assessoria de Coordenação do Planejamento do Sistema Eletro-Energético - ST; 02111-ST-014. Sistema de Transmissão da Região Norte. Belo Horizonte, Fevereiro

One of the few substantial areas in Minas Gerais that is not scheduled to receive the grid is located northeast of Diamantina in the Serra do Espinhaco region, adjacent to a river valley that extends about 100 km. and is about 50 wide. Other unelectrified areas lie to the north and west of Montes Claros, west of the Rio Sao Francisco, and along the border between Minas and Bahia.

The households and communities remaining unconnected to the grid will be challenging to serve either through grid extension or off-grid projects. Much of CEMIG's north and east regions where the grid is less well developed are covered by low mountains and dissected by river valleys. Many of the secondary roads are unimproved, which has implications for the time and cost of installing equipment, servicing systems, and transporting replacement parts.

According to CEMIG, most of the households that will remain unconnected after currently planned grid extensions will be dispersed in individual nonfarm residences and very small villages. Even now, most unconnected villages have less than 50 dwellings and CEMIG plans to electrify all farms by 2002.[36] Historically, the tradition of agriculturists owning their farms is stronger in Minas Gerais than in Bahia or Ceará. This has two effects on the potential market for SHS: 1) a greater share of rural households are not concentrated in villages but are dispersed (increasing servicing costs) and 2) agriculturists have higher disposable income (thus ability to pay for SHS) than nonfarm households.

The estimated breakdown of rural households is as shown in Exhibit 8. CEMIG acknowledges that better information is needed to characterize its rural market and is working with municipal governments to improve its rural market data.

Some of the same characteristics of rural households in Minas Gerais that make them less attractive for grid extension also make them less attractive to receive SHS — distant from existing support networks, relatively dispersed (few connections per unit area), and low-income. CEMIG doubts that the isolated household market would attract private organizations, but would be interested in negotiating a role for them to play.

1998. Companhia Energética de Minas Gerais (CEMIG). Assessoria de Coordenação do Planejamento do Sistema Eletro-Energético - ST; 02111-ST-015. Sistema de Transmissão da Região Norte. Belo Horizonte, Fevereiro 1998.

36 In this respect, the village in which CEMIG's pilot project is operating (that was visited) is atypical of most unconnected households in Minas Gerais.

Exhibit 8: Rural Households

Category	Number of Households	
Connected Rural Households	360,000	
Connected Farms		260,000
Connected Non-Farm Households		100,000
Unconnected Rural Households	170,000	
Connected by end of 1998		50,000
Total Rural Households	530,000	

CEARÁ

When the project team met with COELCE and SETECO in mid-February, the bidding document for the sale of COELCE had not yet been finalized. Consequently, the team suggested inserting language into the bidding document that specifies rural electrification responsibilities. However, this was felt to be unnecessary by SETECO. The bidding document does states that COELCE will provide for rural electrification with costs paid by the state government. Neither COELCE nor SETECO was interested in tinkering with it at that point. The state government of Ceará was concerned about reducing COELCE's sale price by imposing obligations on buyers. In the draft concession agreement, however, there is supposedly a provision that requires COELCE to allocate a percentage of gross revenues to low income programs including rural electrification. This document was not accessible for review.

Prior to the sale of COELCE, the responsibility for rural electrification, including PV projects, was transferred to state government because rural electrification is not financially attractive. After the sale, the state will likely enter into a contract with COELCE to provide rural electricity services. However, all but two of COELCE's staff with expertise in renewable energy have retired. At the same time, SETECO is bolstering its capability to oversee the privatized COELCE and recently created a new energy department.

Both COELCE and SETEC view permissionaires as inferior to COELCE as a delivery mechanism for off-grid services because of market entry costs. In contrast to a new permissionaire, COELCE already has local offices and other service delivery infrastructure. COELCE has offices in each municipality (184), although these will be consolidated after privatization.

COELCE was sold in April, 1998. A major question is the level of investment that the new owners will make for rural electrification. The perspectives about COELCE's rural electrification role stated by its management during the project team's mission in February, 1998, may not reflect the future owners' perspectives.

Update on Renewable Energy Activities

COELCE:

COELCE has been operating a pilot program with SHS and PV for water pumping in fifteen communities serving 3,000 people. The solar equipment was provided by bilateral aid agencies (GTZ for pumps and NREL for SHS). COELCE installed the systems and is responsible for maintaining and replacing the batteries. Villages were chosen that had local associations which requested service. COELCE did not charge monthly tariffs for this service. According to COELCE officials, it tried to charge tariffs but the people did not want to pay since they know that grid power is highly subsidized and a better service. Assuming that COELCE could only charge the approximately R$2.00/month minimum tariff for grid power, it would not have been able to fully recover costs for maintenance and battery replacement. After five years of operation, batteries are beginning to fail in these villages.

OTHER SERVICE PROVIDERS:

A local NGO, the Instituto de Desenvolvimento Sustentavel e Energias Renovaveis (IDER) has been operating a SHS pilot project since fall, 1997. IDER was given a grant from the U.S.-based Solar Electric Light Fund (SELF) to acquire 52 SHS which have been installed in Maceio, a rural settlement along the coast. Local project administrators and technicians were trained and a revolving fund was established.

The 52 participating families each received a SHS that is being financed over four years with a down payment of R$48 and monthly fees of R$12.50. The money is collected and administered by a village association, and is used for maintaining existing SHS, replacing parts, and eventually purchasing additional SHS for future participants. Repayment rates to date have been excellent and no technical problems have been reported.

Key features of this project are as follows:

- *Social issues* - Several visits to the settlement were needed to demonstrate the equipment, identify community leaders, and establish the trust of the community (a previous developer of a wind-powered ice making installation had defaulted on his obligations). To ensure that the village structure and leadership issues were properly considered, the IDER team included sociologists.

- *System characteristics* - The SHS come in kit form, including a Portuguese manual. Components were chosen to minimize maintenance requirements and facilitate owner installation and maintenance. For example, there are plug-in connections between major components that allow replacement without re-wiring. Modules are roof-mounted. All of the units were installed by people from the community who had received training from IDER.

- *Village selection* - Village selection was critical. As a government-sponsored rural settlement, Maceio has a several characteristics that promote project success: a strong local association, a self-selected and stable population that has chosen to live there, and financial support from the government that enhances their ability to pay for the SHS.

- *Economic Sustainability* - To make this type of project sustainable and expand, it would require an alternative to grant funding to become available to finance equipment costs. According to IDER staff, full cost recovery (including importing PV modules on a commercial basis, other capital costs, and labor costs) would increase the required monthly payments from participants to about R$19.

IDER is seeking to interest the federal agency responsible for the settlement program -- INCRA -- in adding SHS to the homes provided to settlement residents. If successful, this would constitute a substantial national market for SHS. In any case, IDER is seeking seed capital to expand its program.

Rural cooperatives are also potential service providers. Although they have not yet offered electricity services, rural cooperatives are also active in Ceará. Based on a map provided by CONBRAC, in principle, cooperatives cover the entire state of Ceará. Each cooperative covers a region that includes several municipalities. Their boundaries could serve as potential permission areas. However, in reality coops are active in only a few of these areas and would need training before they could effectively deliver off-grid SHS-based services.

Delineation of Potential Service Areas

COELCE has been extending its medium and low tension transmission system into rural areas by about 5% per year for the past ten years. This has been financed partly through a World Bank program to support low income farmers by strengthening community infrastructure. COELCE provided information about its current transmission system to the 69 kV level with substations, and regional expansion plans for 230 kV and 500 kV lines. From the maps provided, it appears that one unelectrified area of about 100 km. in diameter lies between Boá Viagem and Sobral. Another area of about 75 km. in diameter lies west of Iguatu. (See the COELCE system map[37] in Appendix A2 in Kozloff 1998) Other unelectrified areas lie along the coast; one is between Acarãu and Paraibapa and another is between Jaguaribe and Apodi. Besides residential and social applications, fishing villages along the coast offer a potential market for PV powered ice-making.

According to COELCE, more unelectrified households are dispersed than concentrated in villages. As with other utilities, COELCE does not have readily available estimates of the number of unelectrified households and villages in different areas, their distance to the grid, or the size distribution of unelectrified villages.

[37] Companhia Energética de Ceará (COELCE). *Sistema de Suprimento do Estado do Ceará.* Fortaleza, Agosto 1997.

BAHIA

Update on Off-Grid Renewable Energy Projects

COELBA:

Now that COELBA is privatized, it will continue to be involved in rural electrification through an agreement with the Bahia state government. The Bahia energy secretariat and COELBA have signed a commercial contract that specifies their respective rights and responsibilities for rural electrification. According to a key provision in the contract, the State can identify and request COELBA to undertake nonconventional energy supply options at the State's expense. COELBA has to indicate within 30 working days if it is interested in undertaking these activities. If COELBA indicates it is not interested, the State may request that ANEEL open a permission to provide these services. According to the contract terms, however, COELBA must agree to this arrangement.[38] Moreover, the license may be terminated by COELBA when it is able to reach the target population through conventional electrification. "Least cost" and appropriate technology are required to be used. In addition, third party financing is allowed.

General agreement says that COELBA will pay up to limit of investment.The recently signed contract calls for R$18 million from the state government, and R$10 million from COELBA — sufficient to serve 32,000 households in 1998. However, because of the higher than expected proceeds from the sale of COELBA, this year about $40 million will be spent on grid extension.

COELBA currently operates a PV pilot program. During a meeting with Hagler Bailly and Winrock/REPSO, COELBA management expressed interest in how a larger scale of operation might offer an attractive business enterprise for COELBA to pursue. With larger scale competitive bidding, SHS capital costs might drop from the level COELBA has experienced in its pilot program (R$1,600 per SHS) to the level cited in the study by the French consultants (R$900).

Local partners in a large scale off-grid program might also include municipal governments. Each municipality has a mayor, and an association of mayors exists in Bahia.

As a result of this meeting, Winrock/REPSO and Hagler Bailly developed a "pre-business plan" for a large scale off-grid SHS service to be operated by COELBA. Exhibit 9 shows one possible division of responsibility that was discussed. The financial test in the draft plan that was proposed to COELBA is based on a comparison with COELBA's costs and revenues for grid extension, as they are currently regulated. In addition to a financial analysis, the proposed plan discusses various sources of risk and ways to mitigate them. A draft of this plan was presented to COELBA in March, 1998.[39] As of this writing, COELBA has not responded formally to it, but

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[38] There appears to be differing interpretations of the permissionaire concept among national, state, and utility officials. According to a recent legal analysis prepared in support of the previous EEP report (Kozloff, 1997), concessionaires (here COELBA) do not have legal control over granting permissions.

[39] Sterzinger, George. *Evaluation of Providing Off-Grid Pvs in the State of Bahia.* Draft Report, 1998.

has suggested that the figures in the plan need to be backed up by international experience. In particular, the reduction in capital costs assumed ($900 for a 50 W system) from COELBA's past experience needs to be better justified.

Exhibit 9: Possible Allocation of Responsibilities for Renewable Energy Services in Bahia

Activity	Coelba	State Government	World Bank	Local service delivery agent
Equipment acquisition	x			
Marketing				x
Installation				x
O&M				x
Financing	x	x	x	
Revenue collection				x
Performance monitoring	x			

With respect to alternative deployment models, COELBA prefers to retain control, ideally through a combination of wholly-owned subsidiaries and subcontractors. In any case, COELBA wants to ensure that its concession will not be encroached upon by permissionaires.

The position of COELBA is that the terms in the concession contract are key. COELBA maintains that its concession contract provides that neither a permission or subconcession can be opened in its service area without COELBA's consent, given that COELBA has paid for the right to serve the full concession area.

OTHER POTENTIAL MARKET ACTORS:

Several other organizations are interested in Bahia's off-grid markets. The State of Bahia energy secretariat (SETEC) is negotiating a contract with a French consortium for a $16.6 million soft loan to provide off-grid electricity services to 50,000 households. (See Exhibit 10.)

Exhibit 10: PV Proposal from French Consortium

Actor	Financial Contribution	Type of Contribution
French GEF	10%	Grant
French Government	30%	Soft loan for emerging markets
Private consortium (EdF, Totale Energy, Transenergy)	30%	Investment
State of Bahia	30%	Retires loan from French government

The first step in this project is a Fr2 million grant from the French government and a Fr0.7 million contribution from the private consortium to study the potential business. If the venture proceeds, the Government of Bahia will require international bidding for equipment. As of April, 1998, COELBA was reviewing the French proposal.

In addition, Idaho Power Company has expressed interest in providing off-grid electricity services in Bahia.

Delineation of Potential Service Areas

As of March, 1997, COELBA had 127,507 km. of medium and low tension transmission lines. Breakdowns of the 2,389 unelectrified villages are shown in Exhibits 11 and 12.

Exhibit 11: Unelectrified Village Size Distribution

Size of village	Number of villages
Less than 20 households	1,431
20 - 40 households	607
More than 40 households	351

Villages with over 20 dwellings generally represent a potential market for both SHS and community applications (such as schools and churches). These number 958. A water pumping system could serve multiple villages.

Exhibit 12: Unelectrified Village Grid Distance Distribution

Distance to the grid	Number of villages
Less than or equal to 5 km.	1,861 (including 42 villages with no distance information)
5 - 15 km.	397
More than 15 km.	131

As of December, 1997, 40.8% of the rural households in Bahia were connected to the grid. Exhibit 14 reflects in part the rapid growth of peri-urban areas in Bahia. Decisions regarding where to extend the grid are based on both technical and political considerations. Representatives of municipalities in Bahia directly petition the Energy Secretary to receive electricity. The State of Bahia has recorded 14,000 requests to receive electricity for villages, public lighting, and other uses.

The most cost effective grid extensions are generally in the peri-urban areas, however, remote villages must receive some of the state and utility investment in extending electricity services.

Most of the contiguous unelectrified regions are in the western part of the state. After planned transmission system expansion, there will remain several unconnected regions ranging from 50 km. to 100 km. in diameter, most of which are in the west and northwest regions. These include areas near the border of Piaui, Tocantins, Goias, and Minas Gerais. The COELBA transmission system map is too large for reproduction in this report. COELBA has arranged with CEMIG for CEMIG to serve some border areas.

Summary of Coopers & Lybrand Rural Electrification Report

The consultants advising the Government of Brazil on power sector reform have prepared a side report on rural electrification (Coopers & Lybrand, 1997)[40] to address issues that were not addressed in their main report. This side report addressed several issues relevant to the World Bank renewable energy proposal:

- The Coopers & Lybrand report noted a bias toward grid extension in rural electrification efforts to date. Cooperatives, regulatory bodies, and financial players should address rural electrification from a broader perspective than only grid extension.[41]

- The report's authors discussed with concessionaires in the process of privatization the most suitable format for a regulatory formula to provide an incentive for penetration of rural areas. The urgency of the privatization process and ANEEL's lack of familiarity with regulatory incentive mechanisms, however, delayed adoption of specific incentives. Still, ANEEL could consider the issue any time over the life of the concession agreements.

- The authors observed inconsistent application of least cost principles. To make the best use of resources, the choice of whether to extend the grid or provide off-grid services must be made on a least cost basis. With respect to grid extension, two factors that have a major effect on costs are load density (which varies among coops from 6 to 833 meters of line per MWh) and energy losses (which average 15%-20%) among coops). As a result of these and other factors, capital, operation, and maintenance costs for grid extension can vary from R$10 to R$300 per MWh delivered.

- The report discusses the development of rural cooperatives' use of the permissionaire model for electrifying rural areas. Reasons for the negative attitude of Brazilian utilities toward the permissionaire model for deploying SHS become apparent in the accounting of the history of territorial conflicts between utilities and cooperative permissionaires. (During February, 1998, a public hearing was held in Santa Catarina to resolve just such a conflict.)

Based on these and other observations, the Coopers & Lybrand report makes the following recommendations:

40 SEN/Eletrobras. Report IV-I. Rio de Janeiro 1997

41 For example, below market loans are available to rural producers for grid extension but not off grid electricity services.

- A national fund to subsidize rural electrification could use BNDES as its agent. Local citizens will press their respective state governments to use the national fund, which will have some type of matching state funding requirement.

- The outcome of these differing views may be some combination of different sources of funds. In any case, administering a national fund for rural electrification will not be part of ANEEL's responsibility.

- The regulatory formula should not discriminate between off-grid renewable energy and grid extension. To avoid such biases, the variable element of the regulatory formula should be based on the total number of customers served, as opposed to the length of transmission lines built.

- Incentives equivalent to the tariff discount given to cooperatives should be available for off-grid renewable energy. The amounts by way of discounts to be granted by the local concessionaire should have, as a reference point, a figure in kWh retailed by the cooperative, both for energy acquired from the concessionaire and for energy for isolated systems. Funding for this initiative could be provided by the National Subsidies Mechanism, providing that it is a broader financing mechanism than the CCC.

- Financing sources for expanding distribution services should include off-grid generation options.

- Discounts for cooperatives should be restricted to the rural market and inversely proportional to load density but limited to a lower ceiling to avoiding creating a disincentive to use off-grid sources of energy.

- The regional diversity requires state-level solutions in terms of policies, rural tariffs, discounts, incentives, etc. Regulatory authority over these issues could be decentralized to state regulatory agencies by agreements with ANEEL. Training on these issues for the states should be provided.

- Regulatory bodies should receive training in integrated resource planning to make them effective in negotiating with concessionaires and permissionaires to determine the most economic conditions of service, appropriate revenue formulae, and corresponding incentives.

- Maximum allowed subsidies should be defined on the basis of least cost alternatives to place off-grid options on an equal footing with grid extension.[42]

These recommendations are currently being considered by the Government of Brazil.

[42] ANEEL does not currently have the staff resources capable of analyzing whether least cost options are being chosen for extending electricity services in specific cases.

Annex D

Household Energy Surveys in Bahia, Ceará, and Minas Gerais: Questionnaire and Results

Questionnaire

Pesquisa de Campo Consumo de Energia
REGIÃO NÃO ELETRIFICADA

[Note: A similar questionnaire exists for a survey of households already connected to the grid.]

nome do pesquisador: **horário inicio entrevista:**

n° do questionário:[A]	**data:**

distancia da sede do municipio:[B]	tempo de transporte desde a sede:[C]

Municipio	localidade	Nome do chefe de família
[D]	[E]	[F]

numero de pessoas:[G] dentro das quais n° de crianças:

Tempo de Moradia	Maior Grau de Instrução	afiliado a uma entidade?
		[H]
	Curso de treinamento	

Atividades no local

Domesticas		agrícola		pecuária		outras:
[I] sim	não	[J] sim	não	[K] sim	não	[L]

Descrição da(s) edificações(s) aonde se usa luz:

	numero de edificações	numero de cômodos	tipo de construção	tipo de teto
	casa	varanda / área sala de visitas: quartos: cozinha: dispensa: banheiro: : **total:** M	N	O
	outros distância da casa em metros			
TOTAL	P	Q		

Condição econômica:

médio e grande proprietario (Ha)	pequeno propr./posseiro (Ha)	parceiro (Ha)	diarista (n° de homem.dia por ano)	outro
R	S	T	U	V

comentário *(continuar no verso se necessario)*

Avaliação da renda media mensal MONETÁRIA

Produção agrícola vendida e produtos derivados vendidos (farinha, rapadura, doces, etc.):

tipo de cultura ou produto	ano retrasado			ano passado		
	volume vendido	preço unitário	receita	volume vendido	preço unitário	receita

despesa **monetária:** - diárias pagas		

total agrícola (liquido)	W	X

Animais vendidos, leite e derivados, ovos, etc., **(somente e se traz alguma renda monetária)**

tipo de animal ou produto	volume vendido	preço unitário	receita	volume vendido	preço unitário	receita

despesa **monetária** - vacinas, remédios --		

total criação (liquido)	Y	Z

Outras fontes de renda (serviço a terceiro, remessa, aposentadoria, emprego publico, costura, artesanato, etc.)

total outras (liquido)	*AA*	*AB*
TOTAL GERAL	*AC*	*AD*
MEDIA MENSAL	*AE*	*AF*

Uso da energia :

Iluminação:

ATENÇÃO! E preciso perguntar o numero de horas por dia para <u>cada</u> fonte luminosa e em <u>cada</u> lugar com muita precisão

n° fonte luminosa	tipo da fonte (velas, lamparina/candeeiro, lâmpada gás butano, etc.)	ambientes	numero de horas por dia
1	AG		AH
2	AI		AJ
3	AK		AL
4	AM		AN
5	AO		AP
6	AQ		AR
7	AS		AT
8	AU		AV
9	AW		AX
10	AY		AZ

TOTAL:

BA			BB

atenção! no caso de uma lâmpada ficar acesa baixinha a noite toda, não contabilizar o numero de horas de funcionamento depois de dormir na tabela. Mencionar apenas no comentário.
comentários:

Tipo	freqüência de compra (em meses)	quantia cada compra	distancia do lugar da compra	custo unitário	gasto médio mensal
Querosene	BC	BD	BE	BF	BG
Diesel	BH	BI	BJ	BK	BL
bujão pequeno	BM	BN	BO	BP	BQ
bujão grande	BR	BS	BT	BU	BV
Velas	BW	BX	BY	BZ	CA
Combustível gerador elétrico	CB	CC	CD	CE	CF
	CG	CH	CI	CJ	CK

atenção! em caso de uso de um bojão grande para iluminação e para fogão, tentar avaliar a duração do bujão se fosse usado só para iluminação

total gasto mensal iluminação:	$R/mês	CJ

tipo de energia (n°Ah bateria, pilhas grandes, etc.)	Equipamento	distância do *lugar de* compra do equipam.	custo equipam (preço de hoje).	potência (em W)	n° de horas de uso por dia	distancia compra das pilhas, recargas etc.	freqüência de compra ou recarga (em meses)	valor da compra ou recarga			**despesa mensal media**
pilhas: - CK	Radio	CL	CM	CN	CO	CP	CQ	CR			CS
- CT	Toca fita	CU	CV	CW	CX	CY	CZ	DA			DB
- *DE*	lanterna	*DF*	*DG*	*DH*	*DI*	*DJ*	*DK*	*DL*			DM
-	DN								valor da bateria	vida útil da bateria	DO
bateria - DP	TV	DQ	DR	DS	DT	DU	DV	DW	DX	DY	DZ
- EA	TV colorida	EB	EC	ED	EF	EG	EH	*EI*	EJ	EK	EL
- EM	antena parabólica	*EN*	*EO*	*EP*	*EQ*	*ER*	*ES*	*ET*	EU	EV	EW
- DX	maquina de costurar	*EY*	*EZ*	*FA*	*FB*	*FC*	*FD*	*FE*	FF	FG	FH
- FI	ventilador	FJ	FK	FL	FM	FN	FO	FP	FQ	FR	FS
-	FT										FU
combustível - *FV*	geladeira	FW	FX	FY	FZ	GA	GB	GC			GD
-	GE										GF
outros - GG	GH										GI
- GJ	GK										GL

total gasto mensal usos domésticos: $R/mês GM

total gasto mensal <u>iluminação</u> + <u>usos domésticos</u>: $R/mês GN

ABASTECIMENTO DE ÁGUA *(para beber, para o banho, outros usos domesticos, para a horta, para os animais, etc.):*

uso da água	donde é puxada a água	Como é puxada a água?	distância entre a fonte e o lugar de uso	profundidade ou desnível entre o nível da água e o lugar de uso
GO	GP	GQ	GR	GS
GT	GU	GV	GW	GX
GY	GZ	HA	HB	HC
HD	HE	HF	HG	HH
HI	HJ	HK	HL	HM

comentário

EQUIPAMENTOS E INFRA-ESTRUTURAS AGRÍCOLAS *(forrageira, motores, etc., começando pelas bombas):*

Tipo	tamanho	custo unitário (de hoje)	consumo energia	despesa anual
HN	HO	HP	HQ	HR
HS	HT	HU	HV	HW
HX	HY	HZ	IA	IB

comentário:

Pratica do credito

nome do credito	finalidade	valor global	duração	n° de parcelas	valor da parcela	aonde é paga?
IC	ID	IE	IF	IG	IH	IJ
IK	IL	IM	IN	IO	IP	IQ
IR					IS	
IT					IU	

comentário:

duração da entrevista:

Results

The following figures show some of the survey results. Figures C-1 to C-3 show the distribution of incomes of households surveyed, comparing it with the income distribution according to the IBGE data for each of the three states.

Figure C-1. Consistency of the Survey Sampling
Income Classes Comparison - BAHIA Survey

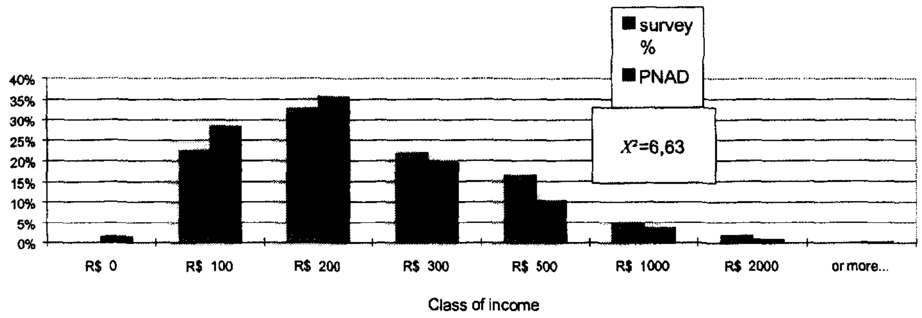


Figure C-2: Consistency of the Survey Sampling
Income Classes Comparison - CEARA Survey

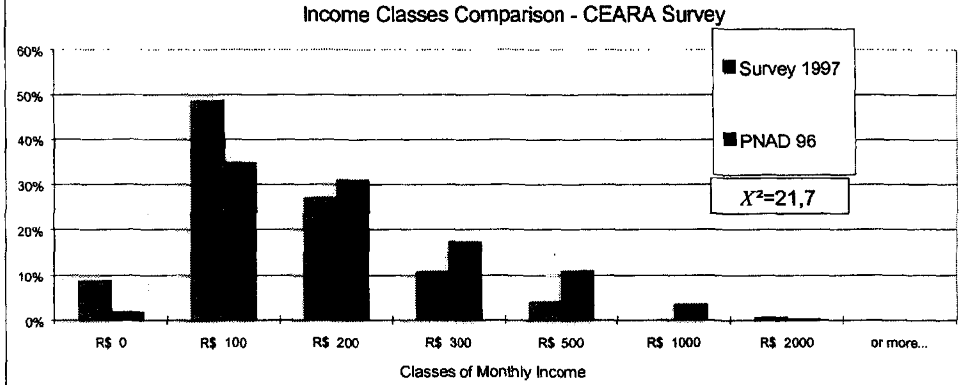
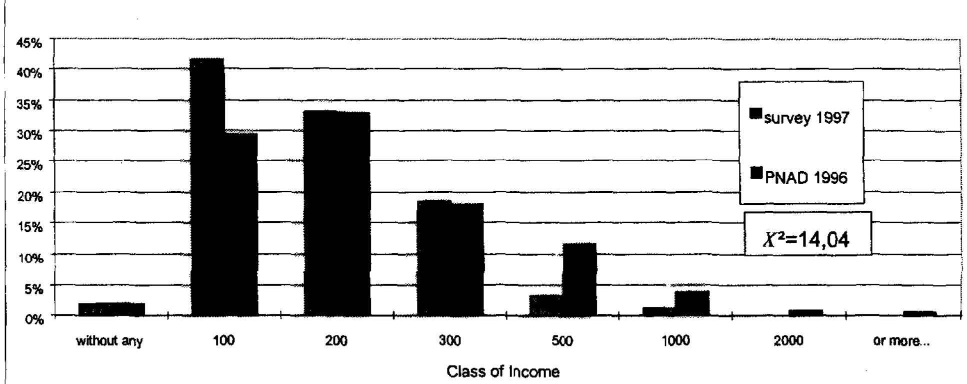
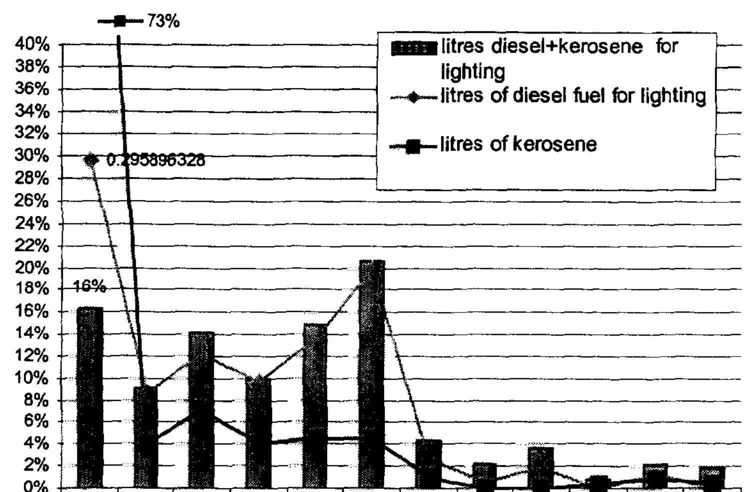


Figure C-3: Consistency of the Survey Sampling
Income Classes comparison– MINAS GERAIS Survey



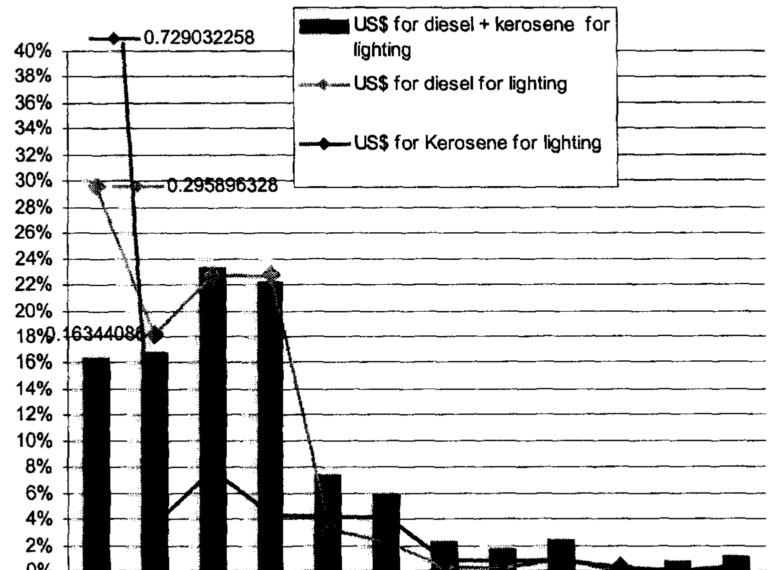
Figures C-4 to C-10 show the energy consumption for lighting and communication purposes and monetary energy expenditures of all surveyed households combined for diesel and kerosene, LPG, candles, drycells and battery charging. In Figure C-11, all of these energy expenditures are combined and sorted according to level of household energy expenditures.

Figure C-4. Consumption of Liquid Fuel for Lighting in Northeast Brazil, 1997



	0 I	1 I	2 I	3 I	4 I	5 I	6 I	7 I	8 I	9 I	10 I	or more..
litres diesel+kerosene for lighting	0.163	0.09	0.142	0.099	0.148	0.206	0.043	0.022	0.037	0.009	0.022	0.019
litres of diesel fuel for lighting	0.296	0.086	0.121	0.097	0.136	0.199	0.026	0.006	0.019	0	0.013	0
litres of kerosene	0.729	0.041	0.071	0.041	0.045	0.045	0.011	0	0	0.004	0.009	0.004

Figure C-5. Monthly Expenditures for Lighting (Liquid Fuels) in Northeast Brazil, 1997



	US$ 0,00	US$ 1,00	US$ 2,00	US$ 3,00	US$ 4,00	US$ 5,00	US$ 7,00	US$ 8,00	US$ 9,00	US$ 10,00	or more..
US$ for diesel + kerosene for lighting	0.163	0.168	0.232	0.222	0.073	0.058	0.017	0.024	0.004	0.006	0.011
US$ for diesel for lighting	0.296	0.181	0.227	0.227	0.032	0.022	0.002	0.009	0	0	0.002
US$ for Kerosene for lighting	0.729	0.037	0.077	0.043	0.041	0.041	0.009	0.009	0.002	0	0.004

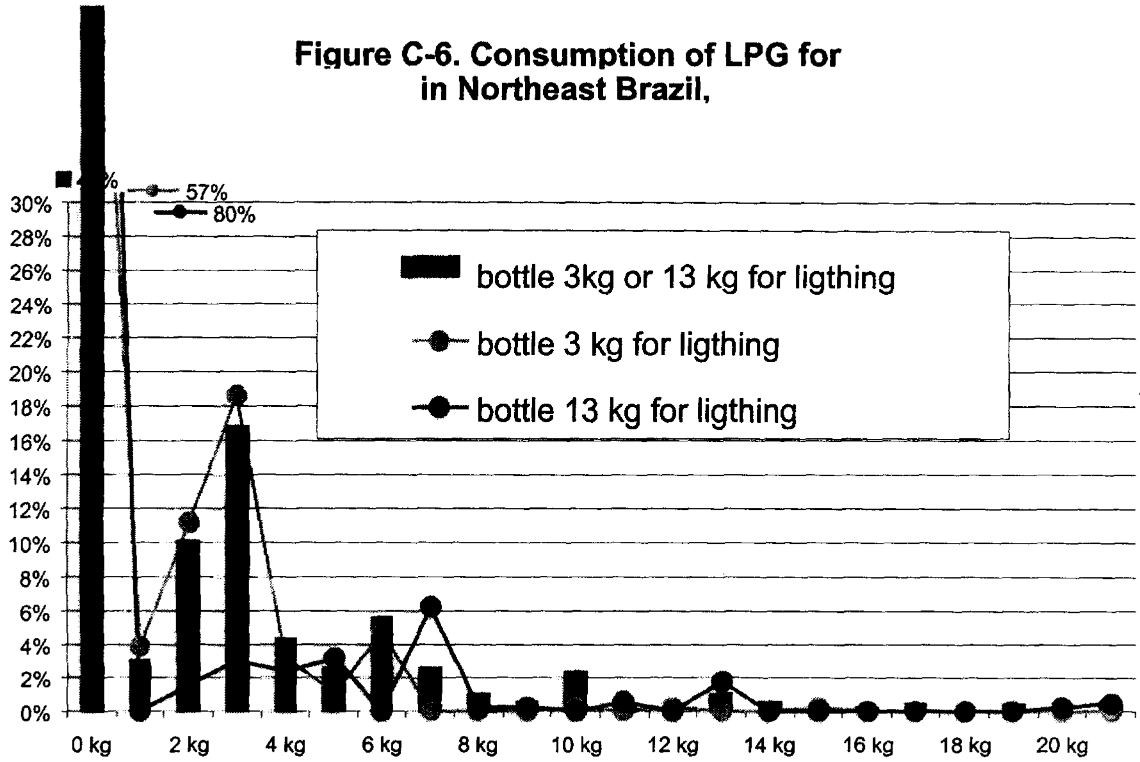


Figure C-6. Consumption of LPG for
in Northeast Brazil,
57%
80%
30%
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
bottle 3kg or 13 kg for ligthing
bottle 3 kg for ligthing
bottle 13 kg for ligthing
0 kg
2 kg
4 kg
6 kg
8 kg
10 kg
12 kg
14 kg
16 kg
18 kg
20 kg

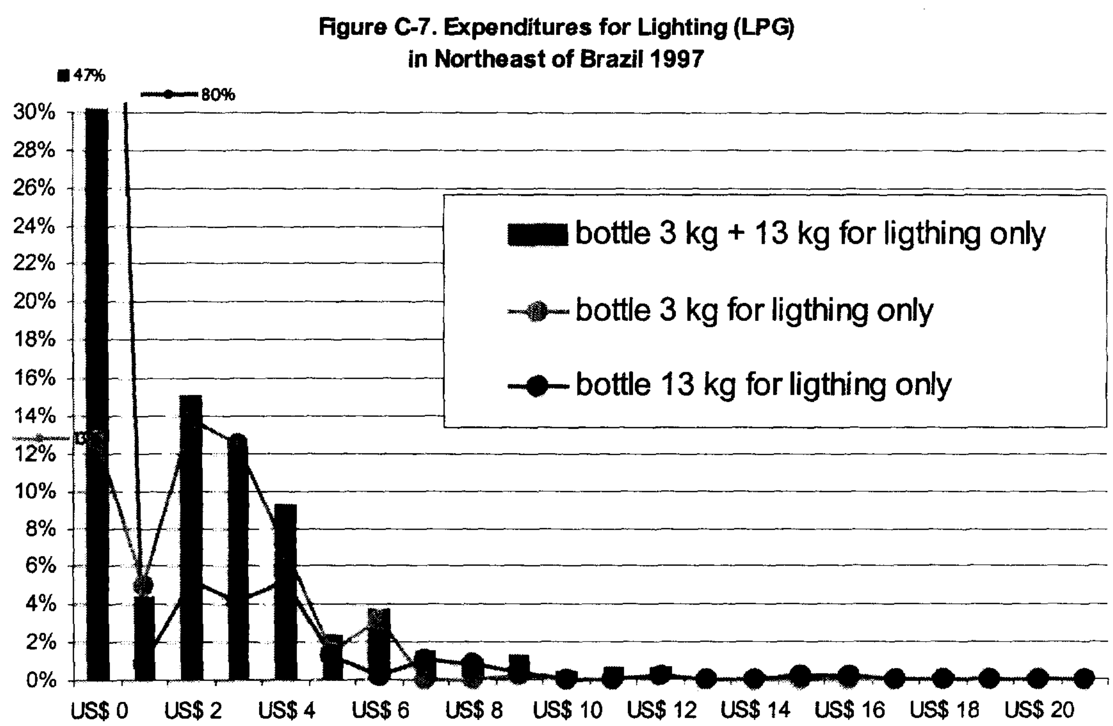
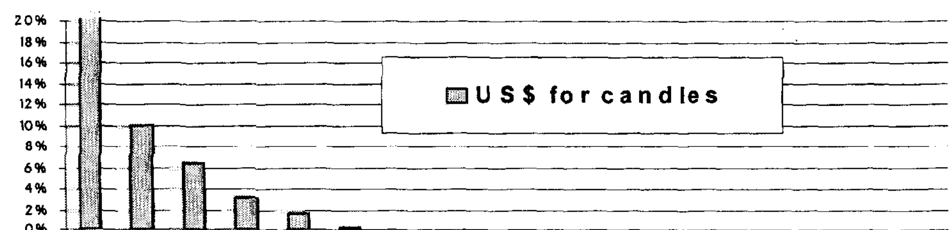


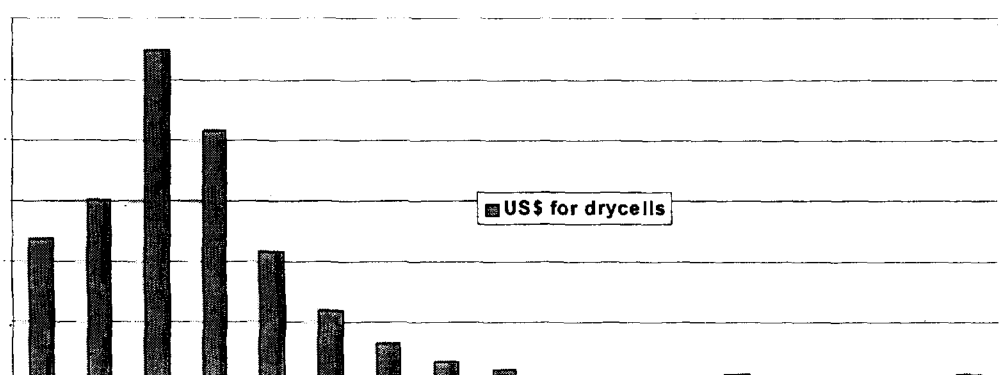
Figure C-7. Expenditures for Lighting (LPG)
in Northeast of Brazil 1997
47%
80%
30%
28%
26%
24%
22%
20%
18%
16%
14%
12%
10%
8%
6%
4%
2%
0%
bottle 3 kg + 13 kg for ligthing only
bottle 3 kg for ligthing only
bottle 13 kg for ligthing only
US$ 0
US$ 2
US$ 4
US$ 6
US$ 8
US$ 10
US$ 12
US$ 14
US$ 16
US$ 18
US$ 20

Figure C-8. Expenditure for Candles (US$/month



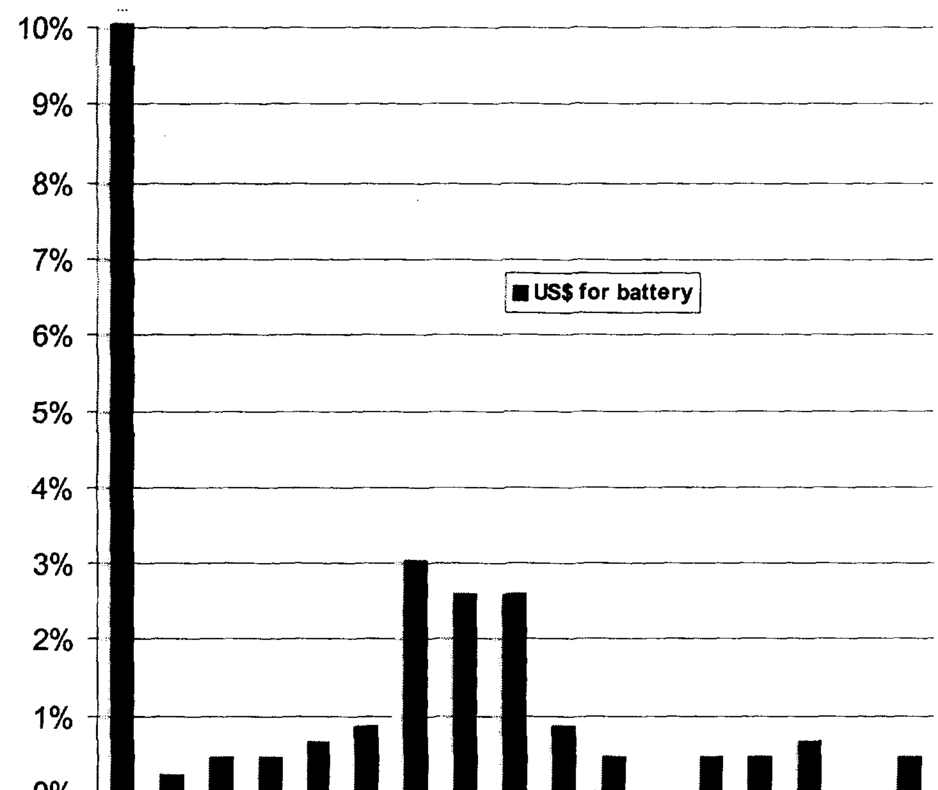
	US$ 0	US$ 1	US$ 3	US$ 4	US$ 6	US$ 7	US$ 9	US$ 10	US$ 11	US$ 13	US$ 14	or more
US$ for candles	0.7823	0.1013	0.0323	0.0172	0	0	0	0	0	0	0	0

Figure C-9. Expenditure for Drycells (US$/month)



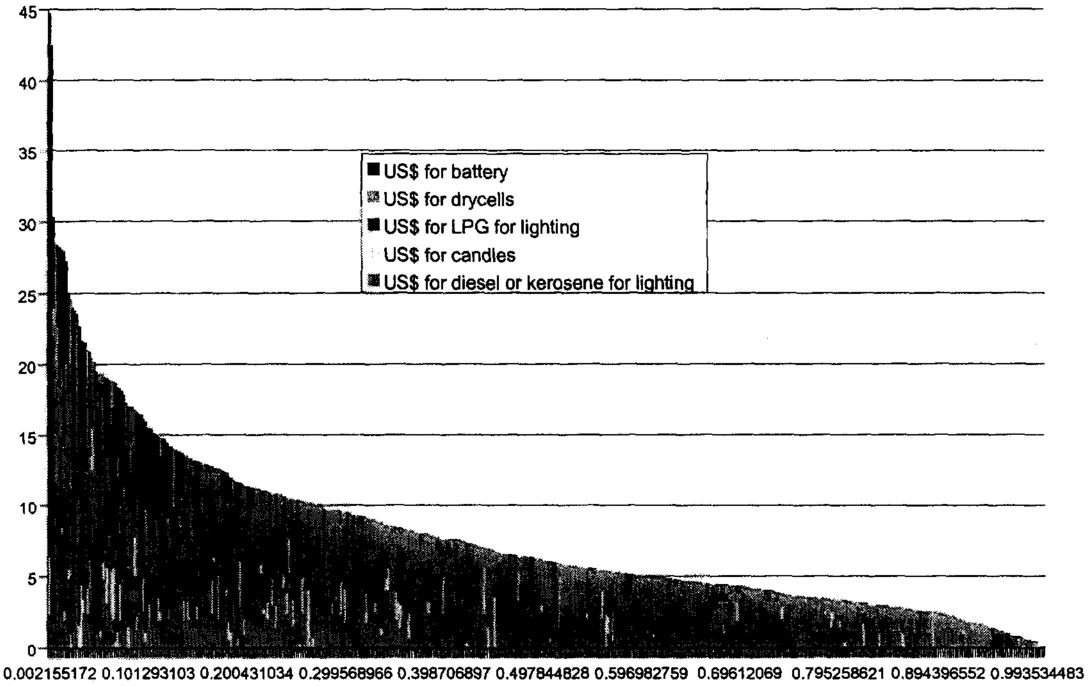
	US$ 0	US$ 1	US$ 2	US$ 3	US$ 5	US$ 6	US$ 7	US$ 8	US$ 9	US$ 10	US$ 11	US$ 12	US$ 14	US$ 15	or more
US$ for drycells	0.119	0.151	0.274	0.209	0.06	0.032	0.017	0.011	0.004	0.002	0	0.006	0	0	0.006

Figure C-10. Expenditure for battery charging (US$/month)



	US$ 0	US$ 1	US$ 3	US$ 4	US$ 6	US$ 7	US$ 9	US$ 10	US$ 11	US$ 13	US$ 14	or more
US$ for battery	0.86	0.002	0.004	0.006	0.03	0.026	0.009	0.004	0	0.004	0.006	0.004

Figure C-11. Structure of Energy Expenditures
in Northeast Brasil, 1997



Annex E

A Proposed Investment Project: Incremental Costs and Market Barrier Reduction Strategy

Incremental Costs of SHS for Households

The analysis here is made in terms of both economic and financial costs of PV systems; in the case of Brazil, these costs can vary significantly due to existing duties and taxes. The economic incremental cost provides an estimate of willingness to pay (WTP) but the financial WTP gives a more realistic measure of the size of the market, i.e., the number of households that can afford to pay the real tariffs. First, it must be conceded that the poorest segment of the market (i.e., Type I households; see Table 3 in main report) can only be served through subsidized social programs, if they exist, in each state. The gap between WTP and current PV prices, even of smaller 30W systems, is so high that this segment is not expected to develop into a sustainable market in the foreseeable future. Second, it is probably not useful to attempt to provide a GEF grant to the market segment that is in the cost range of systems with a capacity of 100W and above. The reason is that the difference between WTP or current energy expenditures and equivalent SHS costs is too small (or even negative in some cases) to matter.

The economic and financial costs for 50W and 100W systems are shown in Table E-1.

Table E-1. Financial and Economic Lifecycle Costs of Solar Home Systems in Brazil (US$)

SHS Size	Installed Cost ($)	O&M/Overhead ($)	Replacement ($)	Total ($)	Net Payment ($/month)
50W, Economic	647	354	216	1,217	13.8
50W, Financial	808	354	216	1,378	17.3
100W, Economic	1,124	435	431	1,990	22.5
100W, Financial	1,446	435	431	2,312	28.9

Notes:
Term: 15 years; discount rate, economic: 12%, financial: 14%.
Economic installed cost includes: profit margin of 15% of CIF, transport cost of 2% of marked-up system and installation cost of $65.
Financial installed cost adds: Import Duties 21%, Industrial State Tax (IPI) 15%.
Net payment is on total less 10% customer down payment (on installed cost).
Source: World Bank Staff

As discussed earlier, no GEF grant is envisaged for SHS of 100W and above, suggesting that the real market for the larger systems must have a WTP of over $29 per month. This results in a very small market segment. The economic tariff of $13.8 for the 50W system suggests a GEF first cost buy-down in the vicinity of $140 to capture customers with a WTP of at least $12.20. The GEF grant represents the incremental cost of the household in shifting to SHS from traditional fuel usage, and at this level it is about 18-20% of the installed SHS cost and 10% of the lifecycle cost.

Given existing duties and taxes for SHS components, the actual tariff is $15-16, implying a smaller market penetration for this segment than at the $12.20 economic tariff (see Table E-2).

Table E-2. Comparison of Economic and Financial Tariffs for 50W Systems

	Lifecycle Costs, $	Equivalent Tariff, $/month (Less DP only)	Equivalent Tariff, $/month (Less DP and $140 GEF grant) and Present Value(PV)
Economic	1,217	13.8 (PV=$1,153)	12.2 (PV=$1,013)
Financial	1,378	17.3	15.4

Source: World Bank Staff.

Incremental Costs and Size of the Household Market. Reducing the first cost (and hence the lifecycle cost) of the 50W system by the $140 GEF grant reduces the tariff to $15-16 per month. Regression analysis of energy expenditures and income levels of households in the three states (see chapter II, Figures 2 to 4) indicate the following approximate market size at the tariff level shown in Table E-3.

Table E-3. Estimated Household Market Size

SHS Size	Suggested GEF Grant, $/unit	Net Financial Tariff, $/month	Estimated Market Size at Given Tariffs (No. of Households)
50W	140 and declining	15.4	66,000
100W and above	0	28.9	7,100

Source: World Bank Staff.

Declining GEF Grant. The GEF grant for 50W systems is designed to equalize the lifetime costs of SHS with levelized baseline expenditures. The time profile of the GEF contribution reflects the dynamics of the Brazilian SHS market. The low population density, the difficulty of terrain and the relative novelty of the technology necessitate a relatively significant GEF involvement up front (compared to other rural electrification projects) in order to gain critical mass—in particular during the first three years, which is the period required for full-scale deployment of installation, operation, and maintenance facilities. However, once economies of scale kick in, it will be possible to reduce the first cost buy down fairly rapidly, and it is expected that after five years the SHS market will be sustainable. (See Table E-4.)

Table E-4. Summary of Proposed GEF Grants and Capacity Installed

Year	1	2	3	4	5	Yr. 1 to 5 Total	Yr. 5 to 10 Total
Grant/50W unit	140	140	140	100	50		
MW Installed/year*	0.6	0.8	0.9	0.9	0.9	4.1	5.1
GEF Grant (US$million)**	1.5	2.0	2.4	1.8	0.9	8.6	0
GEF$/W	2.5	2.5	2.5	1.8	0.9	2.0	0

* Includes 50W and 100W SHS only. Total kW installed will be larger due to PV systems for community centers and private productive applications.

** Applied to 50W systems only.

Source: World Bank Staff.

Service to the very poor rural population who could not afford full payment in the medium term is not included in the project. However, it is not ruled out that a small part of this population could be served, based on the lifeline criteria applied to consumers served by conventional distribution networks, if (i) Federal or State current funds are available to pay for part of the capital cost of SHS systems, and (ii) the users can afford payment of at least operational costs. The question is not: How do we provide for all?, but: How do we increase access? (see Figure 5).

Sustainability. At the end of 5 years, it is expected that cost reductions – particularly in operations and maintenance, and volume purchases achieved through substantial expansion of the consumer base—will obviate the need for GEF grants. Considering other possibilities for cost reductions (such as global drop in PV prices in the next 5 years and/or reduction of taxes and duties), it is expected that system lifecycle costs will have dropped by at least the full initial amount of the GEF grant per unit. At that time, the band of households with the capability and willingness to pay for the lower cost systems will have expanded. The market within these three states could be served at full cost recovery without GEF subsidy.

From the institutional point of view, sustainability of the proposed project would be assured through supporting the strengthening of the state regulatory functions and institutions, and providing appropriate incentives and returns for the concessionaires.

Market Barriers Removal Strategy

Although some mini-grids with diesel or hydro may also be used, the low population density generally requires the installation of individual systems based on renewable energy technologies (RET). Photovoltaic systems are often the least expensive and most practical RET, since solar radiation is more widely available in the dispersed areas than the appropriate level of wind resources. To achieve wide application of RET through the concession mechanism (see below), several key market barriers need to be addressed.

The three main barriers are:

a) Insufficient information for prospective private investors to invest in renewable energy under a concession agreement. These include information on market size and characteristics, the costs of operation and maintenance of systems in dispersed and difficult terrain, adequacy of the proposed tariffs, potential difficulty in tariff collection, etc.

This barrier will be addressed by a combination of actions designed to: (i) educate GOB officials at Federal, state and municipal levels, and the private sector about the benefits of creating a sustainable market for energy services in dispersed areas using least-cost, environmentally clean technologies, and (ii) actively assist in the effective implementation of the concession approach, through contracts that assure a fair return to investors while minimizing public subsidies, development of new guidelines for regulation of RET-based concessions, and establishment of standards that ensure quality equipment and services to consumers. The actions will be focused at both the front-end, to attract qualified private participants, and in the implementation phase, to ensure that concessionaires, regulators and customers are fully aware of each other's rights, functions and responsibilities.

Technical assistance and demonstration activities will be required to remove market information barriers. These activities include the implementation of demonstrations of RET in productive uses, studies to define in detail the household market, programs of promotion and public education, surveys of consumers, a standards and certification program, improvements in the availability of DC appliances, studies to fill the pipeline of projects for productive uses, and marketing seminars for concessionaires.

b) Need for substantial investment resources at the front-end, due to the high capital cost/low recurring cost nature of renewable energy investments. These capital resources are at risk from the potential for consumer default or termination of service, although they are partially mitigated by the consumer installation fee.

The front-end cost barrier will be addressed by: (i) the IBRD loan and GOB counterpart funding; and (ii) the GEF grant for the incremental cost of the renewable energy systems for a limited time until unit costs decline with increased market volume.

c) Market reception of a relatively new technology: Will clients accept it? Will clients be able and willing to pay for the system or service? The reasons for the uncertainty of consumers include inadequate information on the benefits of the new technologies and high first costs.

The risks related to consumer acceptance will be addressed by a combination of: (i) promotion and demonstration programs to educate rural area dwellers on the benefits of the new technologies; and (ii) GEF grants and GOB subsidy funds (if available) to reduce the high first costs to consumers of the new technologies.

Removal of Capacity/Institutional Barriers. This component consists of core support to the Project Management Unit (PMU) at the MME, PRODEEM management, and regulatory bodies at the state and Federal levels.

Annex F

Preliminary Results of Project Financial Simulations

In the following, the first preliminary results of the financial assessment of the project proposed in Chapter 6 are presented. They are based on the spreadsheet model which was developed in Sterzinger (1997). To simplify matters, only 50W SHS were part of this analysis.

The assumptions for the variables and the results are listed in Table F-1. Following are brief comments on several cases which were initially simulated.

BASE CASE with GEF GRANT

The Base Case represents an assessment of the project using the most likely estimates for the relevant variables. They are identical to those underlying the proposed project presented in chapter VI. Please note that the World Bank loan is not specified separately; it is part of the debt of the project, for which an interest rate of 20% was assumed.

1. IRR=16%
2. The interest rate on debt of 20% as well as a ROR on equity of more than 10% seem to be very high, compared to cost of capital for utilities in the US (the former would be 7-8%, the latter around 10%).

Low Tariff and State Grant

1. IRR= -8%
2. <u>Tariff for end users seems to be the single most important variable determining the profitability</u> of the project. Each $ less in tariff decreases the NOI by $1.5 million.
3. Please note that in order to cover O&M and replacement costs, a tariff of $5.15 is required; Currently, in the State of Bahia, for grid extension up to $254 per connection of small users are paid by state government.
4. If the interest rate for debt is lowered to 9%, the IRR increases to –0.3 from –8%.

Lower Interest Rate for Debt

1. IRR: 31%
2. 1% drop in interest rate for debt increases the NOI by about $350,000.
3. <u>An interest rate below market is not required to make the project profitable</u> (see base case) IFF all the other variables are set correctly.

Higher O&M and replacement cost

1. IRR: <0
2. If the O&M is lower, e.g., down 25%, IRR increases to 23% (from 16% in the base base)

Different treatment of O&M costs

In a later version of the spreadsheet model, rather than using a life-cycle estimate for O&M costs, labor costs were modeled explicitly (different levels, number and cost of technical staff). Other cost components of O&M need to be modeled explicitly as well.

Table F-1. Assumption and Results for Financial Simulation

	Base Case	**Low tariff +State Grant**	**Low Interest Rate**	**High O&M**
INVESTMENT				
SHS Cost-50 Watts	454			
Taxes-CIF, %	7			
Taxes-Import, %	11			
Taxes-IPI, %	15			
Installation-50 Watt	65			
MARKET				
Total Market Size	**20000**			
CAPITAL STRUCTURE				
Customer Downpayment	70			
GEF-Year One	140			
GEF-Year Two	140			
GEF-Year Three	140			
GEF-Year Four	100			
GEF-Year Five	50			
State Grant per SHS	**0**	**300**		
Minimum Equity Percent, %	20			
REVENUE				
Tariff for 50 Watt System	**14**	7		**12**
OPERATION AND MAINTENANCE				
Initial Life-Cycle Estimate	**354**			**531** (+50%)
Battery	**50**			**100** (+100 %)
Controller	**10**			**20** (+100 %)
Lamps	**2**			**4** (+100 %)
Fixtures	**30**			**60** (+100 %)
ECONOMIC ASSUMPTIONS AND RESULTS				
Interest Rate for Debt, %	**20**		**9**	
Discount Rate, %	12			
Internal Rate of Return, %	16.1%	**-8.2730%**	**31.4623%**	
Net Present Value of Equity	$1.8 mill.			
Net Present Value of NOI	$2,4 mill	**$0.2 mill**	$5,7 mill	$-3 mill

Source: George Sterzinger.

Annex G

Map

Electricity Transmission Grid in Northeast Brazil

IBRD 30086

FEBRUARY 1999

Joint UNDP/World Bank
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

LIST OF REPORTS ON COMPLETED ACTIVITIES

Region/Country	*Activity/Report Title*	*Date*	*Number*
	SUB-SAHARAN AFRICA (AFR)		
Africa Regional	Anglophone Africa Household Energy Workshop (English)	07/88	085/88
	Regional Power Seminar on Reducing Electric Power System Losses in Africa (English)	08/88	087/88
	Institutional Evaluation of EGL (English)	02/89	098/89
	Biomass Mapping Regional Workshops (English)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	--
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English)	03/90	--
	Symposium on Power Sector Reform and Efficiency Improvement in Sub-Saharan Africa (English)	06/96	182/96
	Commercialization of Marginal Gas Fields (English)	12/97	201/97
	Commercilizing Natural Gas: Lessons from the Seminar in Nairobi for Sub-Saharan Africa and Beyond	01/00	225/00
Angola	Energy Assessment (English and Portuguese)	05/89	4708-ANG
	Power Rehabilitation and Technical Assistance (English)	10/91	142/91
Benin	Energy Assessment (English and French)	06/85	5222-BEN
Botswana	Energy Assessment (English)	09/84	4998-BT
	Pump Electrification Prefeasibility Study (English)	01/86	047/86
	Review of Electricity Service Connection Policy (English)	07/87	071/87
	Tuli Block Farms Electrification Study (English)	07/87	072/87
	Household Energy Issues Study (English)	02/88	--
	Urban Household Energy Strategy Study (English)	05/91	132/91
Burkina Faso	Energy Assessment (English and French)	01/86	5730-BUR
	Technical Assistance Program (English)	03/86	052/86
	Urban Household Energy Strategy Study (English and French)	06/91	134/91
Burundi	Energy Assessment (English)	06/82	3778-BU
	Petroleum Supply Management (English)	01/84	012/84
	Status Report (English and French)	02/84	011/84
	Presentation of Energy Projects for the Fourth Five-Year Plan (1983-1987) (English and French)	05/85	036/85
	Improved Charcoal Cookstove Strategy (English and French)	09/85	042/85
	Peat Utilization Project (English)	11/85	046/85
	Energy Assessment (English and French)	01/92	9215-BU
Cape Verde	Energy Assessment (English and Portuguese)	08/84	5073-CV
	Household Energy Strategy Study (English)	02/90	110/90
Central African Republic	Energy Assessement (French)	08/92	9898-CAR
Chad	Elements of Strategy for Urban Household Energy The Case of N'djamena (French)	12/93	160/94
Comoros	Energy Assessment (English and French)	01/88	7104-COM
	In Search of Better Ways to Develop Solar Markets: The Case of Comoros	05/00	230/00
Congo	Energy Assessment (English)	01/88	6420-COB
	Power Development Plan (English and French)	03/90	106/90
Côte d'Ivoire	Energy Assessment (English and French)	04/85	5250-IVC
	Improved Biomass Utilization (English and French)	04/87	069/87

Region/Country	*Activity/Report Title*	*Date*	*Number*
Côte d'Ivoire	Power System Efficiency Study (English)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91
	Project of Energy Efficiency in Buildings (English)	09/95	175/95
Ethiopia	Energy Assessment (English)	07/84	4741-ET
	Power System Efficiency Study (English)	10/85	045/85
	Agricultural Residue Briquetting Pilot Project (English)	12/86	062/86
	Bagasse Study (English)	12/86	063/86
	Cooking Efficiency Project (English)	12/87	--
	Energy Assessment (English)	02/96	179/96
Gabon	Energy Assessment (English)	07/88	6915-GA
The Gambia	Energy Assessment (English)	11/83	4743-GM
	Solar Water Heating Retrofit Project (English)	02/85	030/85
	Solar Photovoltaic Applications (English)	03/85	032/85
	Petroleum Supply Management Assistance (English)	04/85	035/85
Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea-Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800-KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	--
	Power Loss Reduction Study (English)	09/96	186/96
	Implementation Manual: Financing Mechanisms for Solar Electric Equipment	07/00	231/00
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90

Region/Country	*Activity/Report Title*	*Date*	*Number*
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	--
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	--
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
South Africa Republic of	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	--

Region/Country	*Activity/Report Title*	*Date*	*Number*
Tanzania	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
	Power Loss Reduction Volume 1: Transmission and Distribution SystemTechnical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
	Power Sector Management Institution Building (English)	09/89	--
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	--
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	--
	Rural Electrification Study	03/00	228/00

EAST ASIA AND PACIFIC (EAP)

Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	--
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94

Region/Country	***Activity/Report Title***	***Date***	***Number***
China	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/999
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
	Status Report (English)	07/83	006/83
	Energy Strategy Paper (English)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	--
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88
	Impact of Lower Oil Prices (English)	08/88	--
	Coal Development and Utilization Study (English)	10/89	--
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

Region/Country	Activity/Report Title	Date	Number
	SOUTH ASIA (SAS)		
Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
Bangladesh	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	--
	Managing the Energy Transition (English)	10/94	--
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	--
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86
	EUROPE AND CENTRAL ASIA (ECA)		
Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99

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Turkey	Energy Assessment (English)	03/83	3877-TU
	Energy and the Environment: Issues and Options Paper	04/00	229/00

MIDDLE EAST AND NORTH AFRICA (MNA)

Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
Syria	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	--
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91

LATIN AMERICA AND THE CARIBBEAN (LAC)

LAC Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	--
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	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95

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Brazil	Hydro and Thermal Power Sector Study	09/97	197/97
	Rural Electrification with Renewable Energy Systems in the Northeast: A Preinvestment Study	07/00	232/00
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	--
	Energy Strategy (English)	04/91	--
	Private Minihydropower Development Study (English)	11/92	--
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
Haiti	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English)	03/88	--
	Management Information System Phase I (English)	03/88	--
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comision Nacional para el Ahorro de Energia (CONAE) (English)	04/96	180/96
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
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Saint Lucia	Energy Assessment (English)	09/84	5111-SLU

Region/Country	Activity/Report Title	Date	Number
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99
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	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
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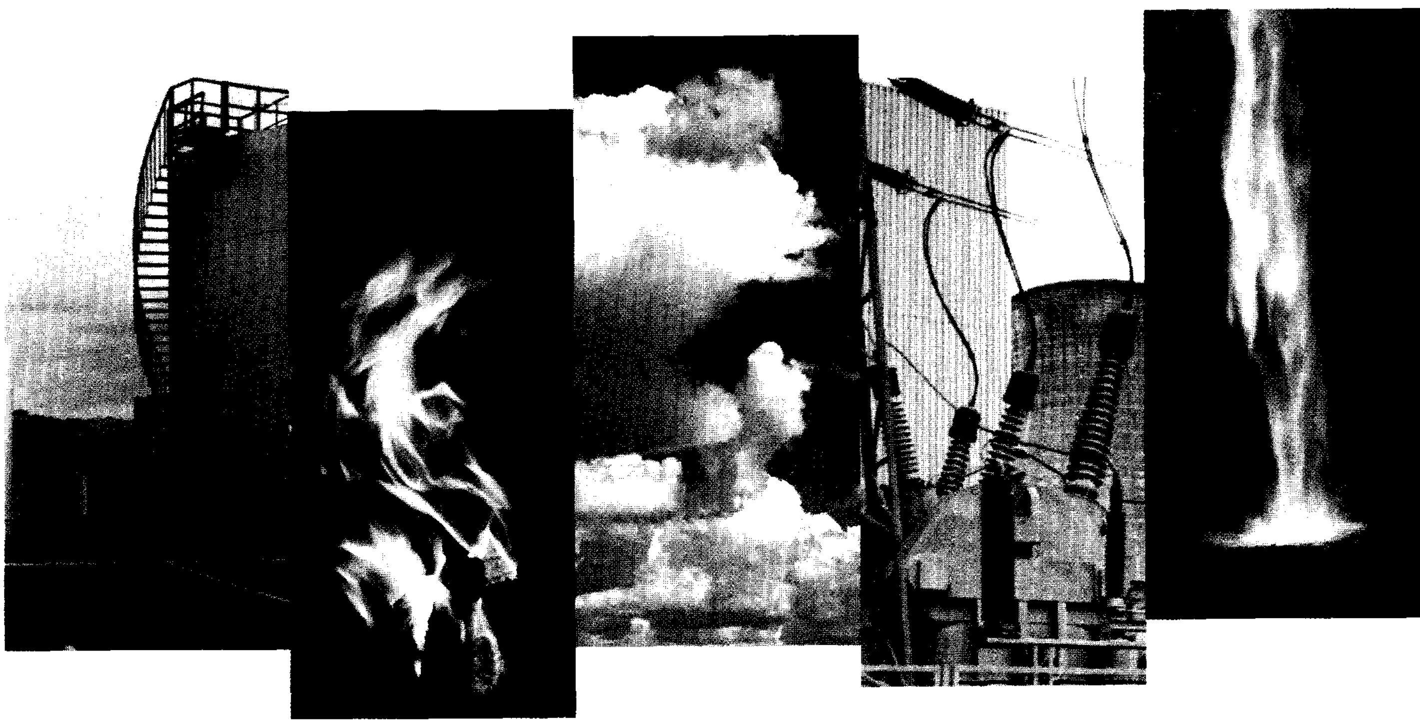

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