ESM 162

ESMAP

Energy Sector Management Assistance Programme

January 1994

Bolivia

Household Rural Energy Strategy

Report No. 162/94

JOINT UNDP / WORLD BANK
ENERGY SECTOR MANAGEMENT ASSISTANCE PROGRAMME (ESMAP)

PURPOSE

The Joint UNDP/World Bank Energy Sector Management Assistance Programme (ESMAP) was launched in 1983 to complement the Energy Assessment Programme, established three years earlier. ESMAP's original purpose was to implement key recommendations of the Energy Assessment reports and ensure that proposed investments in the energy sector represented the most efficient use of scarce domestic and external resources. In 1990, an international Commission addressed ESMAP's role for the 1990s and, noting the vital role of adequate and affordable energy in economic growth, concluded that the Programme should intensify its efforts to assist developing countries to manage their energy sectors more effectively. The Commission also recommended that ESMAP concentrate on making long-term efforts in a smaller number of countries. The Commission's report was endorsed at ESMAP's November 1990 Annual Meeting and prompted an extensive reorganization and reorientation of the Programme. Today, ESMAP is conducting Energy Assessments, performing preinvestment and prefeasibility work, and providing institutional and policy advice in selected developing countries. Through these efforts, ESMAP aims to assist governments, donors, and potential investors in identifying, funding, and implementing economically and environmentally sound energy strategies.

GOVERNANCE AND OPERATIONS

ESMAP is governed by a Consultative Group (ESMAP CG), composed of representatives of the UNDP and World Bank, the governments and institutions providing financial support, and representatives of the recipients of ESMAP's assistance. The ESMAP CG is chaired by the World Bank's Vice President, Finance and Private Sector Development, and advised by a Technical Advisory Group (TAG) of independent energy experts that reviews the Programme's strategic agenda, its work program, and other issues. ESMAP is staffed by a cadre of engineers, energy planners and economists from the Industry and Energy Department of the World Bank. The Director of this Department is also the Manager of ESMAP, responsible for administering the Programme.

FUNDING

ESMAP is a cooperative effort supported by the World Bank, UNDP and other United Nations agencies, the European Community, Organization of American States (OAS), Latin American Energy Organization (OLADE), and 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.

FURTHER INFORMATION

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

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U.S.A.

BOLIVIA

HOUSEHOLD RURAL ENERGY STRATEGY

JANUARY 1994

EXCHANGE RATE

US$1.0 = Bs. 3.2

CONVERSION FACTORS USED

General Units

1 ton crude oil equivalent (toe) = 42 GJ

Fuel	MJ/kg
Charcoal	29.0
LPG	45.7
Kerosene	43.5

ABBREVIATIONS AND ACRONYMS

CDR	Consejo de Desarollo Rural
COBEE	Compana Boliviana de Energia Eléctrica
DEFER	Dirección de Fomento Energetico Rural
DGH	Dirección General de Hidrocarburos
DINE	Dirección Nacional de Electricidad
ENDE	Empresa Nacional de Electrificidad S.A.
ESMAP	Energy Sector Management Assistance Program
INALCO	Instituto Nacional de Cooperativas
MACA	Ministerio de Asuntos Campesinos y Agricultura
MEH	Ministerio de Energía Hidrocarburos
NGO	Non-Governmental Organization
YPFB	Yacimientos Petrolíferos de Fiscales Bolivianos

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INTRODUCTION

In recent years, the Bolivian Government has made substantial progress in restructuring and liberalizing its national economy. As this progress continues, authorities are focusing on the need to further rationalize critical economic subsectors to promote sustainable growth and balanced development.

The urban and rural energy sectors warrant priority attention in the Government's restructuring efforts. Reflecting the low level of per capita income, Bolivia's per capita energy consumption of 300 kgoe is low relative to global (1500 kgoe) and Latin American averages (1000 kgoe). In addition, the significant qualitative and quantitative differences between urban and rural energy consumption highlight the need to establish a national energy strategy which can both moderate the increasing disparities, and foster energy production, conservation, and environmental integrity.

The ESMAP/MEH "Household and Rural Energy Project" has focused on the critical policy and institutional issues facing the Government during this transitional period. 1/ Its recommendations regarding the neglected rural energy sector, in particular, define a strategy which will improve resource allocation by providing priorities and coherence for rural energy planning work, and improve the efficiency of project implementation. Importantly, this strategy will greatly improve the quality of life of thousands of rural households through improved lighting, more efficient cooking techniques, and greater access to electrical power for household and industrial uses.

1/ This report was prepared following a series of visits to Bolivia between 1989 and 1990 by several World Bank/ESMAP missions. The ESMAP team consisted of W. Mostert (Mission Leader) who was assisted by W. Floor (Senior Energy Planner). The international consultants included Messrs. O. Von Borries (Forestry Specialist), F. Butera, C. Sevilla, (Institutional Development Specialists), R. Claros (Economist), E. Delgado (Wind Energy Specialist), F. Hvelplund, C. Sevilla, G. Guzman (Energy Planning Specialists), M. Manon, R. Orozco (Rural Electrification Specialists), W. Matthews, J. Calderon (Gas Specialists), C. Miller (Rural Credit Specialist), C. Ranaboldo (Economist), A. Tarnawiecki (Alcohol Fuels), R. Teran, M. Villarroel (Solar Energy Specialists) and O. Voxland (Rural Electrification and Hydropower Specialist). Mr. J. Mullaney also provided assistance on rural electrification issues. Mr. J. Duran served as in-country coordinator for the duration of the study.

The mission is grateful for the very effective cooperation from the Ministerio de Energía e Hidrocarburos (MEH), and the Ministerio de Agricultura y Asuntos Campesinos (MACA).

EXECUTIVE SUMMARY

1. This study analyzes the issues that need to be addressed to minimize the cost to the economy of the supply of household fuels as well as to minimize the financial cost to households and businesses of the various forms of energy. In addition, the report discusses the appropriate role of Government. In particular, how to strengthen the Government's capability to better formulate, monitor and adjust policies and projects designed to serve its energy policy objectives. To that end, its sets out a household and rural energy strategy, based on the Government's ongoing efforts, that aim to bring about a better level and structure of energy prices and better distribution of access to energy by rural households than is presently the case. This strategy is the result of a collaborative effort, begun in 1989, between the Government of Bolivia and the joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP). It was financed by the Government of the Netherlands.

2. Sector Characteristics. The household energy sector is the largest of all energy consuming sectors in Bolivia. Households account for 44% of total energy use, consuming about 30% of all modern energy (42% of electricity and 20% of petroleum products) and 95% of traditional energy. The household sector is also the fastest growing sector with regards to electricity (7.7% annual growth rate) and LPG consumption (6.7% p.y.). Kerosene consumption fell by 13% per year during the 1980s, partly due to the rise in consumption of electricity and LPG, partly due to the Government's demand restricting policy regarding kerosene.

3. Consumption trends and patterns. Bolivia annually consumes about 2.1 million toe of energy. Its per capita energy consumption of 300 kgoe is low relative to worldwide (1500 kgoe) and Latin American averages (1000 kgoe). Within the urban areas mainly modern energy forms are used, viz. 93% of urban households use electricity; 87% LPG and 11% kerosene. Biomass fuels are hardly used by urban households, in fact, only 10% of urban households use firewood. Rural households mainly (90%) use biofuels. Dung represents 20% and wood some 70% of rural energy use, the remainder being represented by modern fuels. Some 50% of rural households have LPG cookers, although LPG is used only as a supplementary fuel, mainly for cooking purposes. Kerosene is used both as a cooking and lighting fuel, because only some 15% of rural households have access to electricity. In addition, candles are used by the poorest rural households for lighting purposes.

4. In urban areas, electricity demand is expected to continue to rise due to urban population growth and probably rising per capita incomes. Kerosene demand is expected to stagnate or fall, while urban demand for LPG is expected to grow with the rate of population growth, because the urban market share is close to saturation. The use of natural gas in the domestic sector will depend on [i] investments in distribution, [ii] pricing policy, and [iii] general economic development in Bolivia. But given the lead time for the construction of a distribution system and the rate of urban population growth natural gas will not make a major impact on household energy consumption during this decade. To hold urban LPG use constant (in absolute terms) the residential gas connection rate would have to be quadrupled over the projected 1990-95 rate! In rural areas, LPG, kerosene, and electricity demand is expected to rise moderately, if consumers are given reliable access to these fuels.

5. Price trends. The high level of use of modern forms of energy is due to a combination of rising incomes, increased availability of LPG and electricity, rapid urbanization (5.4% p.y.) and a low prices of LPG, kerosene and electricity. The six-fold increase in the price of LPG since 1985 has not changed this situation. Moreover, the electricity tariff remains at about 56% of economic cost. The current price of LPG (0.85 Bs) is above economic cost (0.73 Bs), which is expected to rise even further, (1.06 Bs), because of the need to import LPG to meet internal demand. Natural gas, if it were available to residential consumers, has the lowest financial price. However, the commercial viability of natural gas distribution to the residential sector depends on it competitiveness, which means that its price will have to doubled.

6. Sector Organization. MEH is responsible for formulating energy policies and for regulating the activities of the sector, except for forestry, which is the responsibility of MACA. However, due to lack of funds and qualified staff, MEH is a very weak ministry that cannot properly carry out its functions, whether this be in the field of household energy or in the area of export of natural gas. DINE of the MEH regulates the power sector, including the determination of the tariffs. DIFER is responsible for rural electrification. ENDE and COBEE are the primary entities authorized to develop and operate generating and transmission facilities. ENDE is responsible for planning and coordinating all power system expansion -- generation and transmission -- on the national level. YPFB is engaged in all phases of the hydrocarbon industry from exploration to drilling, production, refining, and marketing. Distribution of oil products is increasingly being left to the private sector. Biomass fuels are collected free of charge by the rural population from their own and common lands, although some are traded through the informal sector.

7. Problems. Despite its importance the household energy sector has not received the policy attention it deserves. Because of its size and its growth rates and overall energy consumption patterns the sector has a key role in determining future supply and demand trends. Specifically, the growing use of electricity may have large macro-economic repercussions. The high degree of direct Government involvement in the urban household energy sector helped to achieve some important results. Yet, its high cost, due to an inadequate pricing policy and subsidies and its urban bias, as well as limited private sector participation in the sector, demonstrates that long-term progress will depend on the redefinition of the balance between the use of direct Government intervention and the use of policy tools that use the market mechanism to achieve the Government's desired energy policy objectives. Two principles should shape this balance: [i] Government intervention is justified only where market failures block the achievement of program objectives; [ii] where such circumstances exist, and where legal and/or institutional obstacles are the main obstacles, it should be determined whether their removal would be more cost-effective than direct Government intervention. As a general rule, the Government should be responsible for guiding policy and shaping public awareness, supporting energy R&D, securing funding for information and education campaigns and monitoring progress. Private sector investors, including NGO's, should have primary responsibility for implementing the strategy.

8. As far as the urban household energy sector is concerned the basic questions are: is the structure of supply is adequate for the needs of the urban populations, and [ii] is pricing policy and regulation promoting the welfare and the objectives of the sector?

Urban Household Energy Policy

9. The Government's urban household energy policy is basically sound. The urban sector is relatively well-regulated and well-served as evidenced by the high incidence of urban LPG and electricity rates. The two most important supply-side issues for the 1990s--the renewal of COBEE's concession and the introduction of natural gas in the residential area--have either been solved or are being addressed. A few issues on the demand side, however, merit attention.

10. The first issue is the Government's **household energy pricing policy**. Both the levels and structure of household energy prices in Bolivia are still inadequate, notwithstanding changes introduced since 1985. Energy pricing policy is still characterized by a cost plus system controlled by the Government, instead of greater competition between fuels through market forces. Further structural change in energy pricing policy therefore is necessary. Such a change in policy should also take into account:

(a) The **long-term structural adjustments of energy supply** in Bolivia. LPG demand will exceed domestic LPG production sometime during the second half of the 1990s. LPG, therefore, may have to be imported. The estimated cost of imported LPG will be higher (Bs. 1.06/kg) than the current price of LPG (Bs. 0.85/kg). For natural gas distribution to be financially viable and thus able to attract privae investors in the gas distribution business and to compete with LPG and kerosene prices without subsidies, natural gas prices for the residential and commercial consumers will have to be increased by at least 100% to US$6.30 per MCF.

(b) The attainment of **distributional objectives**. This sub-issue concerns interregional differences in electricity costs; the question of whether the "natural rent" of the favorable hydropower resources in the La Paz area should accrue to the consumers in La Paz or be used to cross-subsidize the expansion of power distribution to rural areas; and the progressive taxation of the energy consumption of higher income groups. For the poorest 20% of La Paz households, electricity consumption corresponds to 29% of household fuel consumption; in the highest 20% income group it corresponds to 58% Thus, a first step towards the achievement of an income distributional objective is to tax electricity at a higher average rate than other household fuels.

11. The Government should stimulate a political dialogue on the social and economic impact of the policy to cross-subsidize household tariffs with the industrial and commercial consumer tariffs. As far as gas distribution is concerned, the Government should promote more competition on a commercial basis. The basic equity issue of Bolivian household electricity

consumption is that only half of the population has access to electricity. The non-electrified segment of the population spends at least twice as much per month on fuels for lighting than the electrified households, but still has a much lower quality of lighting. Subsidies for electricity consumption reduce the availability of finance for grid expansion and power capacity, and thus restrict a large portion of the population's access to electricity. Secondly, subsidies to urban households are given not only for basic consumption of electricity for lighting, but also to consumption of electricity for household appliances. As a result, a high-income household receives a much higher monthly subsidy than a low-income household. For reasons of both efficiency and revenue-raising, the Government should limit subsidies (through a life-line tariff up to, for example 60 kwh/month) only to low-income households. Instead a tax on electricity consumption to finance rural electrification projects could be considered.

12. The second issue is to define a strategy to deal with the **anticipated LPG demand/supply gap**. Although urban and total demand growth for LPG is expected to be lower in the 1990s than during the previous two decades, demand will outstrip supply before the end of the decade even under the most optimistic of the present supply scenarios, e.g. the discovery and development of new oil and gas fields. Promoting **natural gas** as a substitute for LPG in the residential area should continue to be a key element in the Government's strategy to address the scarcity crisis. But it is still not certain whether it will be possible to establish a pricing structure which will cover costs, allow adequate margins to producers, transmitters and distributors, and still produce competitive end-user prices. Even if a competitive scheme can be developed during the 1990s, natural gas will have only a modest impact on the overall supply demand balance and will require either a relatively high level of subsidy financing during the market buildup phase or a substantial increase in the price of LPG and/or of natural gas. This objective needs to be supplemented by a policy to promote more efficient use of LPG through the diffusion of **improved LPG stoves** and information on economizing cooking practices.

<u>Rural Energy Strategy</u>

<u>Government Passivity During the 1980s--The Consequences</u>

13. Energy consumption of rural households is mainly covered by non-traded biomass resources. A minority of biomass consumption is covered by traded dung and firewood which is supplied through the informal sector. Thus, in practice, there is no Government jurisdiction over biomass supply. LPG and electricity have begun to penetrate the rural market. But as rural incomes are much lower ($250) than urban incomes ($855 La Paz), while the infrastructure and operational costs of commercial energy supply are higher in the rural area, the penetration of these sources of energy has been low and often unreliable. This situation gives rise to three issues:

(a) To what extent can and should Government take on a larger regulating role in rural energy?

(b) To what extent can the market for commercial energy be widened by a more rational structure of supply and institutional support?

(c) Is the present structure of rural energy demand and supply compatible with the economic, environmental and social welfare objectives of the Government, and if not, what level of subsidies (if any) are needed to bring about a more optimal structure?

14. Rural household energy demand is four to five times as high as the rural productive demand for energy. Both are largely satisfied through self-collection of biofuels or through supplies from informal channels of distribution. The supply of LPG and of kerosene is relatively efficient, and about half of the rural households have LPG cookers. In this environment, the MEH seems to have had difficulty in envisaging a regulatory or interventionist role in the rural energy sector. During the 1980s, annual public investments in rural energy projects were less than US$ 4 per rural inhabitant and were directed almost exclusively to rural electrification projects. NGOs stepped into the void created by the absence of public initiatives in the sector and started to develop renewable energy technologies for use in rural areas.

15. During the 1980s, the welfare gap between the urban and the rural households, each comprising half of the Bolivian population, widened as no action was taken to correct for imperfections, inter alia, in the rural energy market.

(a) Whereas the penetration of LPG and electricity in urban households increased from less than 50% to more than 90% during the decade, only 10% to 20% of rural households have access to electricity.

(b) LPG cookers are found in about 50% of rural households, but are used mainly for secondary cooking tasks, due to financial constraints.

(c) Most of the non-electrified households use candles or wick kerosene lamps to meet their needs for lighting, although the use of LPG or pressurized kerosene lamps would result in both lower fuel costs and a substantially higher quality of lighting.

(d) Potential productive rural demands for energy are not satisfied because of the absence of appropriate technology and/or financing mechanisms. While several NGOs and university institutes have made laudable efforts experimenting with new technologies, they have lacked the resources both to base their development efforts on proper market research and to disseminate, on a large scale, technologies that are mature for commercial application.

The Tasks for the 1990s

16. The MEH is rural energy strategy for the 1990s should: (i) increase resource allocation by providing priorities and coherence for rural energy planning work; and (ii) improve the efficiency of project implementation by providing a more rational framework for rural energy planning and implementation. To increase rural electrification rates through the extension of the electric grid will demand high levels of investment to make an impact as well as per connected household. The Government should carefully evaluate whether the benefits of rural electrification are justified by their high economic costs. The Government should note that the argument for subsidies to rural electrification substantially underestimates the rural population's willingness to pay for electricity.

17. Resource allocation in rural energy can best be optimised by concentrating efforts during the 1990s on the implementation of programs that address the welfare needs of the majority of rural households for improved lighting and cooking technologies. The following programs have been listed in order of priority and would aim for:

(a) to lower the cost of lighting, while increasing the quality of lighting levels for households, outside the electrified areas, the access of LPG lamps will be facilitated for households that presently use kerosene lamps or candles to satisfy their lighting needs. In electrified areas, to provide low income households access to electricity through a program that will provide credit to finance their connection costs;

(b) to reduce the cost of rural electrification projects through the development of low-cost mini-hydro schemes and the promotion of rational approaches in project preparation and implementation;

(c) 30% of rural households to use improved stoves through the introduction of improved kitchen designs to reduce fuels needs and increase the consumer's comfort level (see figure 5.6 and Annex V); and

(d) 10% of rural households to be supplied with LPG through decentralized rural bottling plants.

18. Reaching these objectives will require that: (i) the Government create an environment favorable to private sector investment and participation in the energy sector: and (ii) undertake investment activities to implement the rural energy strategy with the help of foreign assistance. The high priority investment opportunities are set out in the table.

Project Title	Total estimated cost in US$	Number of people affected	Implementation period
Rural lighting	20.0 million	1.500.000	1993-2000
Mini-hydro	5.8 million	40.000	1993-2008
LPG bottling	1.0 million	100,000	1993-2000
Impr. kitchen	2.5 million	500,000	1993-2005
Total	28.3 million	2.140.000	

Program 1: Satisfying the demand for lighting

19. Government policy for the satisfaction of basic lighting needs has focused exclusively on the implementation of rural electrification projects. But, rural electrification, which involves high and increasing costs, is a realistic option for no more than those 30% of rural households that are located in relatively concentrated rural areas. A continuation of the policy will be costly in terms of investments and in subsidies and will only benefit a small minority of the rural population, while nothing is done to improve the energy situation of the majority of the rural population which live outside the electrified areas. The estimated marginal cost of rural electricity consumed uniquely for cooking and lighting are higher than those of kerosene and LPG based on the same end-use. These costs range from US¢12-37/kWh to US¢3-44/kWh respectively. While rural electrification can be difficult to justify financialy or economically whn oriented solely on household lighting and cooking, the viability of expanding the rural grid can be augmented if productive end-uses can be strengthened and/or developed (coupled with national tariff regimes). While a small minority of the off-grid households can afford the purchase of a diesel or gasoline-powered standalone generator, the majority meets the demand for lighting by using kerosene wick lamps, candles or LPG lamps. Field studies in a non-electrified area in the Yungas showed that this structure of consumption penalizes low-income households, financially, through a higher monthly bill for fuel expenditures, and qualitatively through the provision of low levels of lighting services. These studies have shown that:

(a) 20% of the rural households which used LPG lamps were able to enjoy a level of lighting consumption that was equivalent to the lighting consumption of electrified households in neighboring villages and for a similar monthly fuel cost;

(b) 50% of the rural households which used kerosene wick lamps paid twice as much monthly on lighting than electrified households for a level of lighting services that was one-sixth of the consumption of poor electrified households; and

(c) 30% of the rural households who used candles paid three times as much as a poor electrified household for a monthly lighting consumption that was 20 times lower.

20. As these households are located in the same area, the use of kerosene wick lamps and candles cannot be attributed to a supply problem, but must be due to the existence of a cash flow problem that prevents the acquisition of a LPG lamp:

(a) The financial value of the monthly fuel savings of about US$ 4.4 during the 3.5 years lifetime of a US$ 40 LPG lamp will provide a candle-using household with an IRR of 124% on its investment. If the acquisition is loan-financed, the yearly savings (fuel savings minus amortization) amount to US$ 38, which is equivalent to 7% of the average yearly income of the poorest 20% of the rural households. If two lamps are purchased the annual saving drops to US$ 28 and the financial IRR to 50%. In addition to the financial benefits, the candle consumer will obtain a welfare increase from the increased level of lighting consumption that can be estimated to have a value of US$ 157 per year.

(b) A household using kerosene wick lamps that purchases two LPG lamps will obtain a financial IRR of 55%, and annual savings of US$ 14. The economic value of the benefits from the increased level of lighting is US$ 81 per year.

21. This non-rational structure of consumption represents a major market imperfection, which warrants Government intervention. The first priority in the rural energy sector is to implement a program to decrease the cost and to improve the level of the lighting consumption of the low-income households that rely on candles and kerosene wick lamps:

(a) In non-electrified areas, the program should aim to reduce the use of candles and of kerosene wick lamps as primary lighting sources to less than 10% of the households by providing loan-financed LPG and pressurized kerosene lamps.

(b) In presently electrified areas, the program should increase the connection rate of kerosene and candle-using households in the area of service to more than 90% by making loans, not subsidies, available for the financing of household connection costs. 2/

2/ There is a lack of concensus among the experts as to the interpretation of the demand curve for lighting and the conclusions derived from it of estimates of consumer surplus. The authors of the report view this curve as a lighting demand curve, while other experts consider it to be merely a plot of unit fuel costs against monthly household use of four fuels for lighting at different levels of consumption and expenditure and not a demand curve (see Annex IX).

22. Such a program for the 1992 to 2000 period can be implemented through the establishment of a US$ 10 million revolving fund, and a yearly provision of US$ 300,000 for the administration of the program. The RDCs will be responsible at the regional level for identifying the target group, fixing annual targets for market penetration, and monitoring the results. Most of this work can be done through subcontracts with NGOs, while the development of the market and the provision of loan finance should be done through the merchants that already sell LPG lamps and through the power distribution cooperatives. The program will improve the lighting situation of more than 300,000 households and reduce the annual lighting cost of these households by about US$ 5.8 million.

23. For households outside the electrifiable areas which currently use LPG lamps, the program will: (i) support the establishment of commercial firms that disseminate PV-systems and PV-lanterns and provide for the servicing of the systems after their acquisition by consumers and (ii) support the diffusion of the systems by a combination of loans and subsidies to the consumers.

Program 2: Development of cost-efficient micro and mini-hydro projects

24. The substantial investment needs of rural electrification projects make it imperative to maximize the potential for cost savings and the benefits from the availability of electricity. To this end, MEH should, inter alia, implement a program that aims to realize to exploit cost-efficient micro and mini-power schemes.

25. Some 65 mini-hydro plants with a total capacity of approximately 80 MW are in operation. Half of these units are used for mining, the others are for "urban" use, of which some have combined mining/urban uses. Further expansion has been restricted by the low population density in areas with high physical mini-hydro potential: 14% of the national territory has mini-hydro potential, while the optimal sites are located in 5% of the national territory. In the latter, only 66 communities with between 100 to 2,000 inhabitants could be identified. These communities permit the development of sites in the 20 to 100 kW range. In addition, some sites can be developed for isolated mining projects and saw mills. Finally, some agro-processing uses can be identified for direct-shaft mini-hydros, e.g. coffee. Thirty "optimal" projects have been identified with costs per kW in the US$ 1,200-1,500 range. Total investment volume of these projects is US$ 5.8 million, and their total capacity is 4.3 MW. Assuming a load factor of 17% the expected energy cost will amount to US$ 0.10/kWh. Over the next 10 to 15 years it is estimated that there is a market for the development of 100 microplants and 10 miniplants with a total capacity of 3.5 MW. These projects can provide electricity to 40,000 persons.

Program 3: Increased rational use of energy for cooking

26. The widespread use of fuelwood and dung for cooking does not result from a particular preference for the fuel, but from the low levels of income in rural Bolivia which forces

the households to rely on "free" fuels. Local scarcities of fuelwood lead, first, to the consumption of dung as a fuel, then to a switch to LPG and kerosene cookers. Roughly 50% of the rural households currently have LPG cookers, although LPG is used mainly for secondary cooking tasks. The present system of supplying LPG in cylinders by trucks from the urban bottling plants is relatively efficient, perhaps a more widespread use of LPG in the rural areas can be served better by a more decentralized system of LPG bottling.

27. The objective of energy policy in this area is to improve the comfort and the environmental compatibility of the continued use of biomass fuels. The policy should also ease the process of transition towards the use of modern fuels by modernizing the system of LPG distribution to the standards required by rural mass consumption. The proposed program has two components that aim: (i) to test the feasibility of promoting the use of more efficient stoves through the promotion of "improved kitchen designs," and (ii) to implement a US$ 1 million pilot project involving the establishment of two decentralized systems of LPG bottling and distribution in rural areas.

28. The justification for the decentralized LPG bottling project is the following. Although Bolivia boasts of one of the most comprehensive LPG supply and distribution systems and most LPG-intensive economies in the world for its GDP per capita level, there are apparent shortcomings and less-optimal operations which could be improved upon. There is still excessive centralization of the bottling function, the lack of supply reliability (particularly in peri-urban and rural areas), and excessive centralization in an institutional sense. For, YPFB not only owns and operates the production, supply and storage facilities, but also the bottling plants, and is even involved in a limited way in cylinder distribution. The LPG supply and distribution system would benefit from an institutional restructuring by limiting YPFB's role to the gross supply function, leaving distribution in bulk and bottled form to the private sector. Also, a strategy of bulk distribution through the establishment of small decentralized bottling plants should be actively pursued. This would mean the supply of LPG in bulk to a series of rural networks consisting of small, simple storage and bottling stations that each serve a specific rural population center. The networks will improve the stability of supply to the immediate areas and reduce cost, because they decrease the average distance between the bottling operation and the consumer. In view of possible higher future cost for imported LPG such cost reducing policies should be vigorously pursued.

29. In order for these programs to be successful a credible effort is required, both financially and institutionally. This implies, inter alia, a sustainable system of long-term financial and technical support which means that program implementation, including a consumer lending mechanism, should include private sector participation. Such long term support for the rural electrification activities can be provided, in particular, through the Electrification for Alternative Development Project and its implementational arrangements initiated by USAID. Similar institutional and financial arrangements should be developed for the sale and distribution of LPG and kerosene lamps, including private sector participation. The LPG pilot bottling plant project should be executed and financed by the private sector, although credit should be made available, to help investors overcome their urban bias by demonstrating the rural operation's financial

viability. A change in Government policy to transfer the LPG bottling function entirely to the private sector would create the right climate for the private sector to take an active interest in the expansion of the energy service system into rural areas. The improved kitchen design project, for which donor financing should be sought, can be executed in tandem with the expansion of the LPG distribution and bottling network in the rural.

30. In addition to these high priority investments, the study has identified a number of supportive activities that aim to improve (i) the quality of project selection, preparation and implementation in general; and (ii) the economic and financial viability of rural electrification projects in particular. These supportive activities are set out in the table.

Project title	Total estimated cost (US$)	Implementation period
Project prioritization	1.0 million	1993-2005
Water pumping study	0.5 million	1993-1995
Kiln improvement	0.5 million	1993-2000
RE seminars	0.1 million	1993-1996
Productive RE use promotion	0.5 million	1993-1996
Reforestation study	0.2 million	1993-1994

31. The impact of the existing and the potential productive demand for energy in Bolivian agriculture on the national energy balance is low. But new technologies that make better use of available low-cost potential energy resources can make an important contribution to improving the economic condition of Bolivian farmers. Unfortunately, the efforts to develop new energy-related rural technologies in Bolivia have: (i) lacked market focus, (ii) been too localized, and (iii) not been supported at the national level by clearly-defined goals and the financial backing necessary for large scale, market-oriented technologies. The concept of the "project cycle" that comprises the whole chain from project identification, preparation, appraisal implementation, monitoring and evaluation of the results of a project is not well understood by even the most professional of the NGOs. Efforts have mostly focused on the technical testing of equipment, while the testing of methods for a larger-scale diffusion of successful technologies has been neglected.

32. The program in this field seeks to strengthen the promotion of new water-pumping technologies by basing the initiatives on "management by objectives." This involves: (i) focusing efforts on the development of technologies that have genuine market prospects, (ii) setting targets for their market penetration, (iii) defining appropriate financial and institutional mechanisms for their effective diffusion in the market and (iv) carefully monitoring and evaluating the results of the projects. The MEH and MACA will need to collaborate closely on the implementation of the projects; the MEH can support the technical work, MACA the diffusion work. Since the demand for

energy for water pumping is likely to be the fastest growing segment of rural productive energy demand during the 1990s, testing and promoting of successful technologies in this area will be a key priority. Processes for the low-cost drying of crops are another priority area as well as the reduction of fuel use in the energy-intensive rural brick industries.

33. To improve the financial and economic viability of rural electrification projects, MEH should implement a program that aims: (i) to increase the quality of the technical-economic feasibility work for rural electrification projects; and (ii) to promote the productive demand of rural electricity. These objectives can be realized through seminars for public and private sector staff involved in the planning and implementation of rural electrification projects on least-cost designs, and the use of demand analysis as a tool to fine tune project designs. Also, a pilot project to promote productive uses of electricity should be implemented to test the cost-efficiency of new approaches to tackle this issue.

34. Finally, concern about the pressure on fuelwood resources in certain areas of Bolivia has led FAO and some bilateral donors to implement reforestation programs that incorporate energy use as one component. Unfortunately, these projects are not based on a viable concept for sustainability. Therefore, there is a need for medium- and long-term sustainability of energy-related forestry projects.

Reforming the Framework for Rural Energy Planning and Implementation

35. The second objective of the rural energy strategy is to improve the efficiency of project implementation. To achieve this objective, the framework for rural energy planning and implementation must be reformed. While MEH formulates the general objectives and goals that have to be reached, the local implementing agencies should define how the goals can best be reached in individual areas. In the proposed system:

(a) At the strategic level, MEH in consultation with MACA would have four tasks: (i) formulating the objectives, the policies and the programs for sector work, (ii) identifying sources of finance for the execution of programs, (iii) preparing calls for tenders for the implementation of program components that are carried out at the national scale and selecting executing agents, and (iv) monitoring and evaluating the results of the policies and programs.

(b) At the functional level, the RDCs would have four tasks: (i) regional implementation of the national energy programs, (ii) publishing the regional call for tenders for the selection of regional executing agencies, (iii) preparing the plans for the implementation of "collective" energy systems in their regions, such as rural electrification projects, and (iv) monitoring the performance of the executing agencies in their regions.

(c) At the operational level, relevant NGOs, university institutes and private consultants would have two tasks: (i) executing the individual program components, and (ii) serving as consultants in technical advisory committees during the preparation of new program proposals. The executing agencies would be selected on the basis of the quality of the proposals they have prepared in response to a call for tender.

36. COFER has been replaced by a small unit in the MEH, the "Direccion de Fomento de Energia Rural" (DIFER). This Direccion would be responsible for the four strategic level tasks defined above and, in addition, act as executive secretariat for the "Consejo Directivo de Planificacion Rural de Energia" which would be established with representatives from MACA, MEH, the Corporaciones de Desarrollo and the NGOs. The function of the "Consejo" would be to identify national priorities for interventions, investments, and policies for two to three years at a time on a rolling basis, and promote the coordination of activities at the horizontal level between MACA and MEH, and at the vertical level between the MEH, the RDCs and the NGOs.

37. However, due to lack of funds DIFER cannot yet function effectively. The structural reasons for this ineffectiveness (lack of funds, low salaries) will persist unless some action is taken. One proposal is to create a semi-autonomous, and technically well-staffed, Advisory Unit inside MEH (similar to the unit that developed the National Energy Plan), that will be financed by a bilateral donor. This temporary Advisory Unit will train DIFER staff, prepare project proposals for the investment and supportive activities identified in this report for donor funding, assist to operationalize funded 'projects as well as the institutional arrangements recommended by this report. Also, to assist the "Consejo" in developing a methodology to achieve the objectives set out in paras. 1.23 and 1.24. This Advisory Unit could function for a period of 3-5 years after which its functions can be taken over by DIFER. This transfer should be facilitated by the fact that all actors participating in the "Consejo" will have improved skills and abilities as well as proven methodologies and procedures to continue the tasks developed by the Advisory Unit. Finally, the Government needs to allocate sufficient funds to enable DIFER and the "Consejo" to perform its functions effectively.

I. BACKGPOUND

A. Economic and Demographic Trends

Physiography and Population

1.1 Bolivia had a population of 7.4 million in 1990, half of which was rural (i.e. lived in population centers of less than 2,000 inhabitants according to the definition of INE, the National Statistical Institute). Urban population had grown at a rate of 5.6% per annum during the 1980s versus a total population growth of 2.6% per annum and a rural population growth of 0.8%. If the growth rates for total and urban population continue, the share of rural population will drop to 39% in the year 2000 and to 30% in 2010.

1.2 The national territory is large compared to the population and covers 1.1 million km^2. The territory can roughly be divided into three major physiographic zones, with the following population and area:

Table 1.1: Physio-Ecological Zones in Bolivia

	% of area	Population mill.	Population in %
Highlands (Altiplano)	16	2.8	38
Valleys (Valles)	19	3.1	42
Lowlands (Llanos)	65	1.5	20

1.3 The Highlands (Altiplano), at an average altitude of 3,800 m a.m.s.l. are found in the western part of the country, and comprise major parts of the departamentos La Paz, Oruro and Potosi. Ecologically, the Highlands exhibit both temperate and subtropical zones.

1.4 The Valleys, at an average altitude of 1,500 m a.m.s.l., cross the country from Tarija in south to La Paz in north and comprise major parts of the departamentos Tarija, Chuqusaca, and Cochabamba. Ecologically, the Valleys fall into temperate and subtropical zones.

1.5 The Lowlands are found in the eastern and northeastern part of Bolivia at altitudes averaging 500 m a.m.s.l., and comprise major parts of Santa Cruz, Beni and Pando. Ecologically, the Lowlands are tropical in the north and varies from subtropical to temperate in the south.

1.6 Although population density per km^2 is low, the pressure on arable resources is high. About 5.7% of the national territory is cultivable, but only 2.6% is cropped. Pastures cover 30% of the territory. Half of the land area is forested. Most forests are found in the thinly populated northern and eastern lowlands and extending into higher elevations on the eastern side of the mountain range. The remaining 15% of the territory is without any agricultural use. To promote a higher compatibility between potential agricultural resources and the size of the population, Bolivian Governments over the years have been encouraging migration from the Altiplano to the Lowlands.

The Bolivian Economy

1.7 Bolivia has the second lowest GDP per capita in Latin America and the Caribbean; its per capita GDP was US$ 570 in 1988, compared to a regional average of US$ 1,840. During the three decades prior to the mid-1980s, the state was the dominant economic force in the economy. The larger mines were nationalized under the management of the state-owned Bolivian Mining Corporation (COMIBOL). The state petroleum company YPFB became the sole concessionaire for hydrocarbon exploration and development. The state set up numerous productive enterprises and accounted for over two thirds of total investment and about a fifth of manufacturing output. At the same time, private sector activities were largely conditioned by Government decisions, through subsidized credit programs directed at particular sectors, an extremely complex and protective system of tariffs and quotas, allocation of foreign exchange, and marketing boards and price controls for most agricultural commodities.

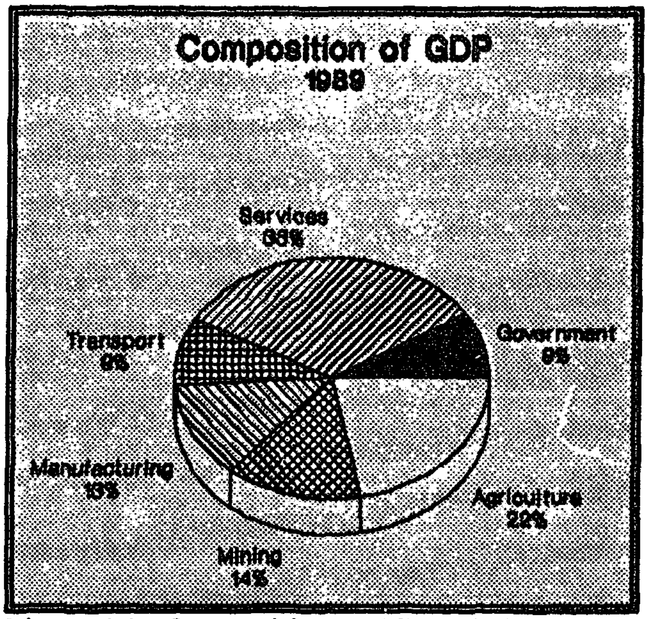

Figure 1.1: Composition of GDP, 1989

1.8 At the end of the 1970s, the limits of the state-led approach had become apparent. Continued economic growth was undermined by three structural weaknesses. First, the central government was extremely dependent on the external sector for its income: Export and import taxes accounted for over half of the Government's revenues. Yet the export basis was eroded by: (i) an overtaxation of the two key exporters--COMIBOL and YPFB, which saw their investment possibilities restricted, (ii) the collapse of international tin prices and (iii) the rapidly diminishing quality of available tin ores. Second, central planning was unable to enforce rational investment priorities because of strong regional and interest group pressure, that resulted in costly "white elephants" and unsustainable heavily subsidized sector development programs. Third, partly as the result of the first two characteristics, savings in Bolivia were largely insufficient to finance the level of expenditure. The consolidated public sector deficit continued to increase as expenditures rose and state enterprises, inter alia YPFB, were forced to keep consumer prices at subsidized levels.

1.9 The combined result was a huge accumulation of foreign debt. During the first half of the 1980s, the imbalances resulted in negative GDP growth rates and hyperinflation. The infrastructure remained poor. The desired structural change towards a more industrialized economy was not achieved. The contribution of manufacturing to GDP was not higher in 1988 than in 1965 when it was 15%, (See Figure 1.1).

1.10 New governments elected in 1985 and 1989 have taken full account of the need to reverse past trends. Government policies have succeeded in controlling inflation through monetary discipline. Substantial moves have been made to liberalize the economy and encourage the private sector. Negotiations and the purchasing of debt at low rates have contributed to a substantial reduction in foreign debt. These policies have reversed previous economic decline, with GDP growth of 2.5% per annum in 1987-89, against -2% per annum in 1980-85.

B. The Energy Sector

Energy Demand

1.11 Bolivia annually consumes an estimated 2.1 million toe of energy. Reflecting the low level of per capita income, per capita energy consumption of 300 kgoe is low relative to worldwide (1500 kgoe) and Latin American averages (1000 kgoe). Basically, energy consumption in the urban centers is based on hydrocarbon fuels and electricity, whereas rural demand is covered principally by biomass resources. Because of the large size of the rural population biomass energy covers about 40% of total final energy demand. Transport consumes more than half of final petroleum product demand. Most of electricity consumption is consumed by urban households and the commercial/public sector (see Table 1.2).

Table 1.2: Structure of Final Energy Consumption, 1989

	Petroleum Products	Biomass (fuelwood, animal dung, bagasse, charcoal)	Electricity
Household/Commercial/ Public sector	22%	95%	60%
Agricultural sector	<1%	2%	<1%
Industry and Mining	8%	3%	39%
Transportation sector	69%	0%	0%
Total	51%	42%	7%

Source: ESMAP/MEH project estimates.

Energy Resources and Supply

1.12 Bolivia is relatively rich in energy resources, which permits the country to be self-sufficient, and to export natural gas to neighboring countries. In addition to the biomass resources (woodfuels, dung and bagasse), Bolivia's energy resources comprise hydroelectric power (some 18000 MW, of which only 300 MW has been exploited) and oil and gas (about 24 mtoe and 3.8 tcf respectively). Solar radiation is high, whereas the wind resources are modest.

1.13 As metal mining declined, the hydrocarbon sector became the strategic sector for Bolivian development. Hydrocarbons provide the major source of foreign exchange earnings (31% of export revenues in 1989) and of Government revenues (44% in 1989). An important infrastructure exists in the form of transmission and distribution pipelines for white products and natural gas that extends to the major cities. But difficulties emerged:

(a) Production of petroleum liquids (including condensate) averaged 21,000 bpd in 1989, down from a high of 49,000 bpd in 1973. This decline is attributed to well depletion, declining oil discoveries and obsolete machinery. Oil exports, which were 32,000 bpd in 1973 have now virtually ceased and a critical issue for Bolivia is whether it can maintain its current self sufficiency in oil products through the 1990s. A reinforced exploration effort will be needed to discover new liquids reserves. Natural gas production accounted for 81% of national hydrocarbon production.

(b) Domestic consumption of natural gas amounted to 0.014 TCF whereas exports to Argentina were 0.18 TCF. But due to the discovery of important gas deposits in Argentina, the interest of the Argentinean Government in Bolivian gas declined and the Bolivian Government was under pressure to reduce export prices. This intensified the efforts to search for alternative exports of gas to Brazil. Finally, a scheme was designed to export gas indirectly through the use of natural gas in a 525 MW power plant in Porto Suarez at the Brazilian border and the export of electricity to Brazil.

1.14 The power sector comprises about 600 MW of capacity. Current power generation is evenly divided between hydro and thermal generation, the latter supplied by a combination of gas turbines and diesel engines. The country's large hydro resources remain relatively expensive to exploit and gas represents the least-cost expansion solution in the medium term. Diesel generators and small hydros are the primary power sources for the isolated system. Small isolated systems and small, autonomous production plants account for nearly one-fourth of total installed capacity and represent 15% of total electricity production.

Sector Institutions

1.15 MEH is responsible for formulating energy policies and for regulating the activities of the sector, except forestry which is the responsibility of the Ministry of Agriculture. These functions are carried out by two main departments within the Ministry, one responsible for hydrocarbons (DGH), and the other for electric power (DINE). Power tariffs and petroleum prices are set by the MEH. The "Corporacion de Fomento Energetico Rural," COFER, funded through the MEH, is responsible for rural energy and alternative forms of energy. Overall sector planning is provided by the "National Energy Plan" unit, which is a team of consultants "permanently" employed by the MEH.

1.16 Power Sector regulation. The National Electricity Directorate (Dirección Nacional de Electricidad--DINE) of the MEH is the national entity which regulates the electric power sector. DINE administers the national energy policies formulated by the MEH and related to the electric power sector, including determination of electricity tariffs for all companies operating in the sector. DINE's regulatory role is authorized through the National Electric Code of 1986, which also details aspects of concession contracts for power generation and distribution. COFER is responsible for rural electrification planning, but its current funding is only sufficient for maintaining basic office functions. The National Cooperative Institute (Instituto Nacional de Cooperativas--INALCO) is the regulating body for all Bolivian cooperatives, including electric power cooperatives.

1.17 Generation and Transmission. ENDE and COBEE are the primary entities authorized to develop and operate generating and transmission facilities. Part of ENDE's mandate as the national power company is to assure the supply of electric power to all distribution companies, as well as to some mining and large industrial consumers. The privately-owned COBEE is responsible for electric power supply and distribution to La Paz and (bulk sales) to Oruro. In addition, the various regional development corporations (RDCs) pursue the development and operation of rural development projects, some of which include power generation components, e.g., Cordepando in Cobija.

1.18 ENDE officially is responsible for planning and coordinating all power system expansion-- generation and transmission--on the national level. Ideally, the development and operation of new generating plants should be compatible with least-cost development plans prepared by ENDE. By law, all plants generating over 5 MVA must be operated by ENDE. COBEE's operation of large generation facilities is made possible through a grandfather clause in existing legislation. Entities other than ENDE may develop and operate plants generating less than 5 MVA, as long as it is coordinated with ENDE's national plan.

1.19 Hydrocarbons. The state oil company, YPFB, is engaged in all phases of the hydrocarbon industry from exploration, to drilling, production, refining and marketing. Distribution of oil products is increasingly being left to the private sector. YPFB produces around 65% of Bolivia's total gas production, the balance is produced by private contractors Tesoro and Occidental (US) and Perez Company (Argentina). Natural gas for internal market consumption has always been supplied exclusively by YPFB. In 1990, however, Perez Company began to supply around 50% of internal market needs. YPFB's share of the export market is presently around 56%.

C. Energy Policy Objectives

General Objectives

1.20 In general terms, the objectives for energy policy in Bolivia are: (i) to cover internal demand, (ii) to do it in the economic and environmental least-cost way, (iii) to increase export income, and (iv) to provide financial revenues for the public sector.

Operational Objectives

1.21 The immediate operational conclusions from these objectives for post-1985 energy policy were dictated by the needs of the structural economic reform program. First and foremost, the Government had to implement:

(a) measures that provided greater autonomy to the public energy enterprises and promoted private sector initiatives;

(b) pricing reforms to increase economic efficiency, to improve the financial situation of the energy companies and to generate revenues for the state budget; and

(c) investment projects that either led to increased exports (the Puerto Suarez complex of projects for exports to Brazil) or to substitution of local consumption to free up supplies for exports (the extension of natural gas distribution into the commercial and household sectors).

1.22 As a result, issues that were intrinsic to the energy sector were pushed to a secondary level, such as the need to:

(a) address the welfare and policy implications of: (i) the continued reliance of the rural population on biomass fuels, and (ii) the low penetration of electricity in rural areas.

(b) provide an incentive framework for energy savings and operational efficiency; and

(c) review, monitor and manage the environmental implications of energy consumption and investment.

Household Energy Issues

1.23 The basic question to be addressed is the same for both the rural and the urban part of a household energy strategy: What is the most rational structure of energy consumption from a macro-economic point of view? Because of the great qualitative difference between the issues of urban and rural household energy, they will be dealt with separately.

1.24 The energy consumption of urban households is covered by the "commercial" energy sector. This sector is served by professional energy supply firms and regulated by public pricing policy, rules and norms. Here the basic questions are: (i) whether the structure of supply is adequate for the needs of the urban population and (ii) whether the public policy of pricing and regulation promotes the welfare and efficiency objectives in the sector.

1.25 Energy consumption of rural households is mainly covered by non-traded biomass resources. A minority of biomass consumption is covered by traded dung and firewood which is supplied through the informal sector. Biomass supply, therefore, falls outside Government jurisdiction. LPG and electricity have begun to penetrate the rural market. But as rural incomes are lower than urban incomes and the infrastructure and operational costs of commercial energy supply are higher in the rural area, the penetration of these sources of energy has been low. This situation gives rise to three issues:

(a) To what extent can and should Government take on a larger regulating role in rural energy?

(b) To what extent can the market for "commercial" energy be widened by a more rational structure of supply and of institutional support?

(c) Is the present structure of rural energy demand and supply compatible with the economic, environmental and social welfare objectives of the Government, and if not, what level of subsidies are needed to bring about a more optimal structure?

II. URBAN HOUSEHOLD ENERGY DEMAND

A. Socio-economic Profile of Urban Household Energy Demand

2.1 The urban population in Bolivia (persons living in villages of more than 2000 inhabitants) comprised about 3.3 million persons in 1990, divided into 670,000 households. About three quarters of the urban population lived in cities of more than 10,000 inhabitants, and La Paz, Santa Cruz, Cochabamba and El Alto made up about 80% of city dwellers. The average number of persons per household was 4.6 and falls with increasing income. La Paz households in the lowest income quintile include, on average, 5.6 persons; the richest one percent of households, 3.25 persons.

2.2 The average per capita income of La Paz households was US$ 855 and average annual expenditures per capita US$996. 3/ Most of the urban households can be classified as poor--80% of households in La Paz have an annual per capita income of less than US$ 850. The upper 20% of households have an average income per capita of US$ 2,25 and per capita expenditures of US$ 1,828. They comprise the middle class plus the richest 1% of the population. (see Figure 2.1) The richest 1% of households in La Paz have an average income per capita of US$ 13,437 and average expenditures which are half of that. With some simplification, it can be said that the average consumption pattern of the upper 20% shows the future trend for the pattern of urban demand in Bolivia, whereas the consumption of the upper 1% is divorced from the medium- and long-term reality of the majority of the urban population.

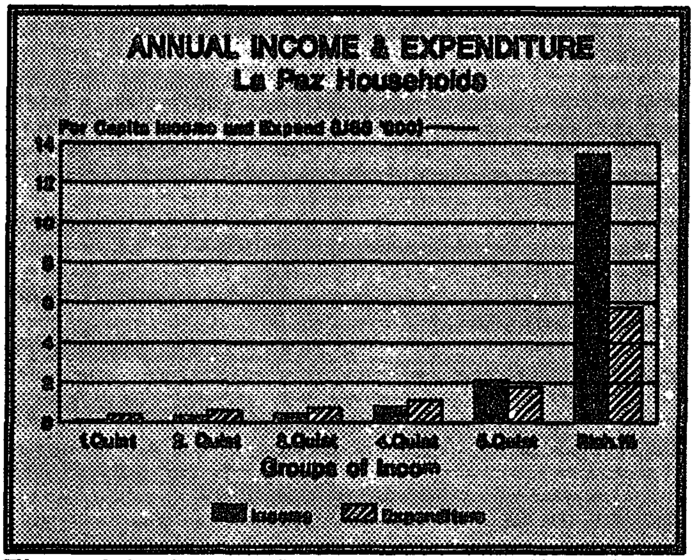

Figure 2.1: Average Income and Expenditure by Population Quintile

2.3 The most prevalent household fuel is electricity which is found in 93% of urban and 98% of La Paz households (see Annex II, Table 3.2). LPG is used by 87% of urban households, and kerosene by 11%. Charcoal is hardly used at all and fuelwood is used by 2% of the population in La Paz and by 10% of the urban population in general. The urban consumption of woodfuels

3/ The figures are results from the World Bank/INE financed socio-economic survey of fall 1989. The "illogical" result of expenditures being higher than income, illustrates the difficulties in obtaining reliable income data. Household income is usually underreported by households. Therefore, although the income data from the survey are quoted in this report, there is no doubt that the data on total expenditures provide a more appropriate estimate of the level of income for the lower income groups.

is low for a country of Bolivia's per capita income, whereas the penetration of LPG and of electricity is high. This is because wood resources near the urban centers are rather scarce and because the hydroelectric resources and the domestic production of LPG are relatively cheap. Even in Trinidad, which has abundant wood resources, less than one fifth of urban households use fuelwood to any extent.

2.4 Final urban household energy demand in 1989 was 317,000 toe, which amounted to 16% of national final energy demand. Although use of electricity is more widespread, LPG was the dominant household fuel with 152,000 toe, electricity was second with 126,000 toe, whereas kerosene and "other fuels" demand amounted to 14,000 and 24,000 toe.

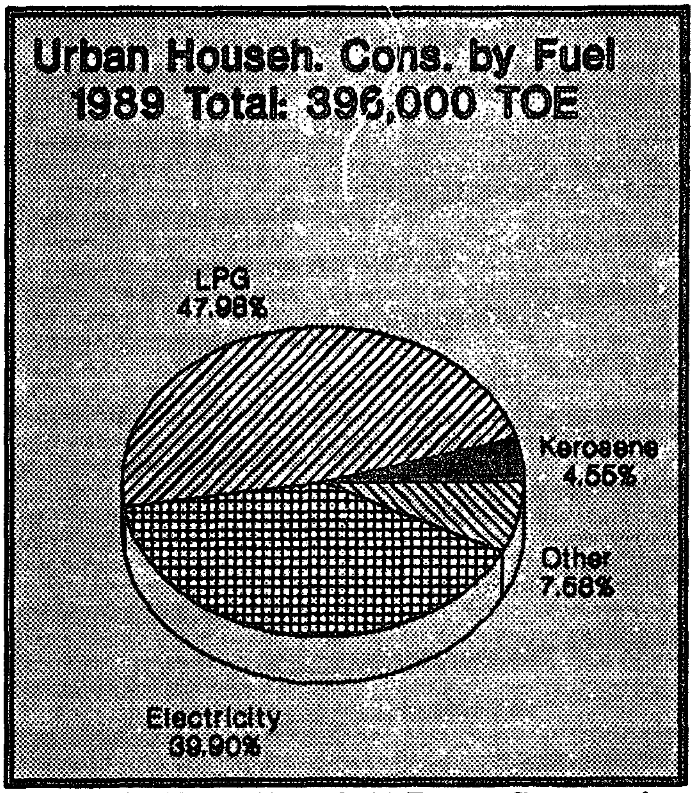

Figure 2.2: Urban Household Energy Consumption

2.5 While total expenditure per capita triples between the lowest and the highest income quintile, energy consumption in physical units of commercial fuels doubles: the richest 20% of households consume 15.6 kgoe per month and per capita, the poorest 20% consume 7.6 kgoe (see Figure 2.3 and Annex II, Table 3.4). The positive income elasticity of electricity consumption is high 4/, whereas LPG consumption increases only little and kerosene consumption falls with increasing income.

2.6 The high income elasticity of electricity demand is due to the superior quality and comfort of electricity in use with household appliances, such as refrigerators and freezers; and its exclusive application in electronic equipment. The high cost of these appliances puts them outside the reach of the majority of the urban population. Because of the high urban connection rate of electricity, very few urban LPG and kerosene consumers use these fuels for lighting. These fuels are used almost exclusively for cooking. Since the energy consumption for this basic need is about the same for low, as well as for high income households, the income elasticity of LPG demand is rather modest. The income elasticity of kerosene demand is negative, as LPG cookers offer better comfort. Less than 12% of electricity using households use electricity for cooking -- hardly any of the poorest 40%, but more than a third of the richest 20%. Therefore, there is relatively little

4/ Data from COBEE on the average consumption of kWh/month show that 4.2% of users consume 84 kW; 39% consume 104; 56% consume 279; and 0.2% consume 2132.

competition between electricity and the hydrocarbon fuels in the household market, i.e., the fuels serve different needs.

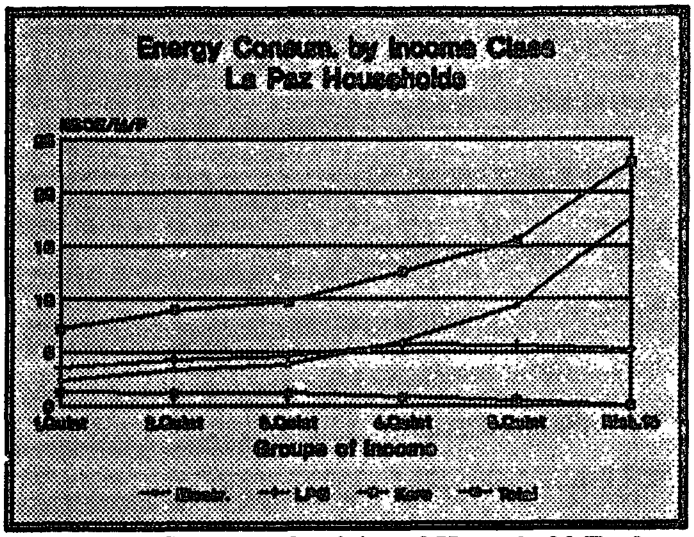

Figure 2.3: Income Elasticity of Household Fuels

2.7 The richest 20% of the households use on average 50 bolivianos (US$ 20) per month on household energy, the poorest 20% spend 29 bolivianos (US$ 11). Yet, in both relative and in welfare terms the burden of energy expenditures is higher for the poorest households: They amount to 15% of income and 5.7% of total expenditure of the poorest 20% of La Paz households; the richest 20% use 3% of their income or 3.8% of total expenditures. On the whole, though, the burden of household energy expenditures for urban households is relatively modest by international standards.

B. Evolution in the Prices of Household Fuels During the 1980s

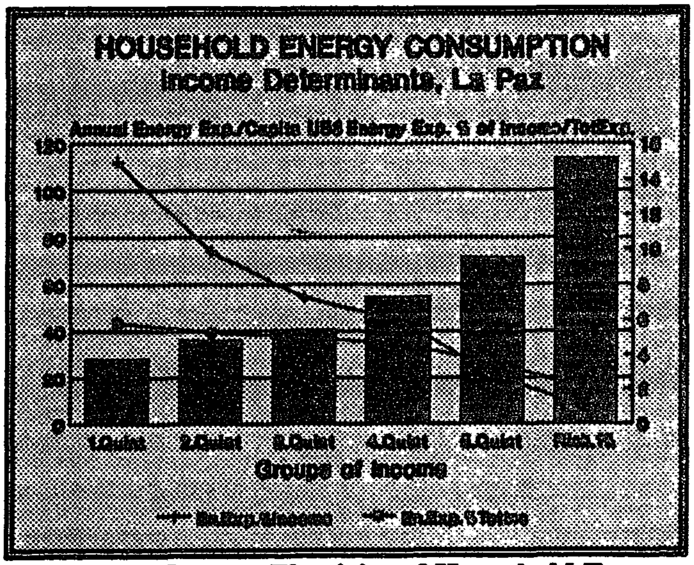

Figure 2.4: Income Elasticity of Household Energy

2.8 A substantial shift in the **relative and the real prices of household fuels occurred during the 1980s decade.** (see Figure 2.5) In 1980, for political reasons, hydrocarbon fuel prices were below their economic cost. During the first four years of the 1980s, the real prices of all household fuels fell as hyperinflation led to a series of distortions in both real and relative levels of Government controlled prices. Prices of woodfuels were not controlled by the Government, but were pulled down by the fall in the real prices of LPG and kerosene. With the adoption of the Government's **economic stabilization plan in 1985**, fuel prices were increased to cover their economic cost. Hydrocarbon fuels were increased to international levels, that is, to their true opportunity cost. This led by the end of the decade to a six-fold increase in LPG prices over their 1980 level and to a tripling of kerosene prices. Bolivia never had an explicit policy of subsidizing urban electricity demand. Therefore, the consequence of price stabilization reform was that electricity prices were restored to their 1980 level.

C. Trends in Urban Energy Demand

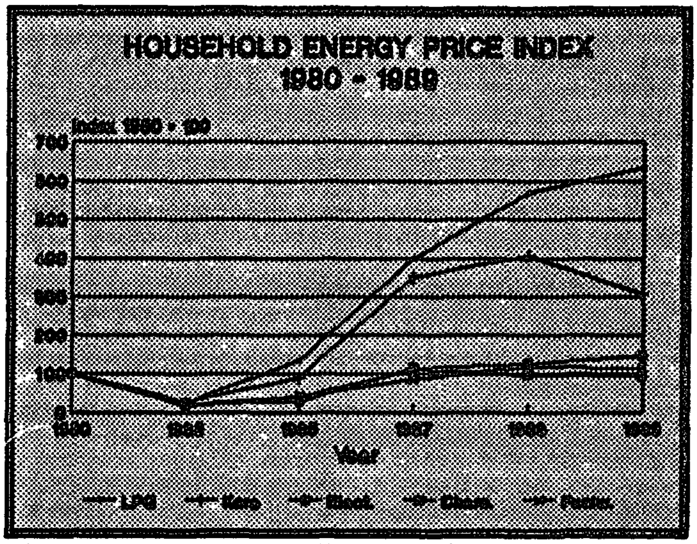

Figure 2.5: Household Energy Price Index

2.9 **Electricity** and LPG have been the two fastest growing urban household fuels. In spite of the six-fold increase in its real price and a stagnating national income, LPG demand (see Figure 2.6) increased by 6.7% per year from 1980 to 1989. In the second half of the 1980s, the growth in demand was choked off, because demand had outstripped the availability of domestic supply, and imports were not feasible. Statistics about LPG use by sector are not available for this period. But because of the economic crisis during the 1980s, it is not likely that LPG demand in industry and commerce reached the average growth rate. LPG demand was fueled by the annual 5.4% growth in the urban population and a market share that grew by replacing fuelwood and kerosene for cooking. That the market share increased in spite of the eroding competitiveness of LPG prices confirms the impression that (i) that little cross-price elasticity of demand exists between the fuels--LPG is the preferred fuel for cooking and electricity for lighting--and (ii) the burden of fuel expenditures is bearable even for low income households.

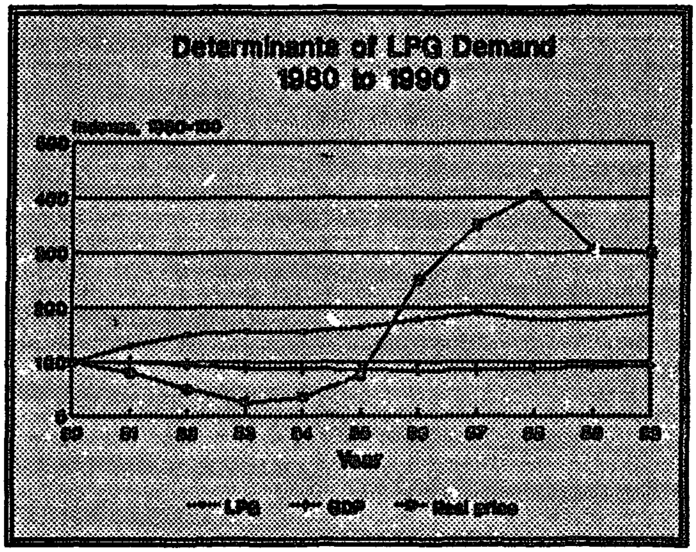

Figure 2.6: Evolution of LPG Demand

2.10 From 1970 to 1989, household **electricity demand** grew by 7.7% per year, and increased from 175 GWh per year to 700 GWh. Since the electricity-intensive mining sector declined during the same period, and industrial production made little progress, the share of household demand in total electricity consumption increased from less than 25% to more than 40% (see Figure 2.7). Demand was particularly strong from 1975 to 1980, when per capita income increased slightly. Income per capita fell during the 1980s, but household electricity demand continued to be fueled by the growth of the urban population, and an increase in the connection rate of urban households. The slower rate of growth compared to the second half of the 1970s may indicate that household electricity demand is influenced by the increase in income to a certain extent; but could also be attributed to the limiting effect of the higher penetration rates.

2.11 **Kerosene** consumption fell by 13% per year during the 1980s, as the Government imposed a demand-restricting policy to make its use in the cocaine industry more difficult. **Natural gas** had not yet penetrated into the domestic market during the 1980s, as the urban distribution companies were commencing operations.

2.12 The **long-term implications** of the income and price elasticities of household fuel demand are:

(a) The share of **electricity** in urban household demand will grow. Demand growth will continue to be strong, fueled by both urban population growth and probable rising per capita incomes. Including demand other than household, electricity consumption is expected to grow somewhere between 5.5% and 6.7% per year.

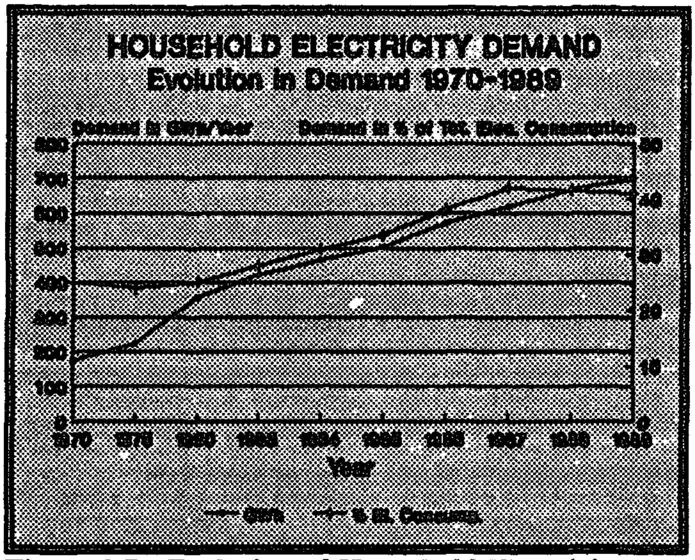

Figure 2.7: Evolution of Household Electricity Demand

(b) The demand for **kerosene** should continue to stagnate and fall.

(c) The urban market share of LPG is close to saturation. Urban demand for LPG can be expected to grow more or less with the rate of urban population growth.

(d) The use of **natural gas** in the domestic sector during the 1990s will depend on: (i) the investments in distribution, (ii) the pricing policy and (iii) the general economic development in Bolivia. Most of the household market for natural gas is expected to be in new urban developments, where the distribution infrastructure can be established at relatively low cost. But even under the most optimistic scenario for natural gas development, the rate of urban household growth will far exceed the residential gas connection rate.

III. GOVERNMENT POLICY FOR URBAN HOUSEHOLD ENERGY

A. The Economic and Financial Cost of Urban Household Fuels

3.1 For the majority of the population, cooking represents the major use for household fuels and the one area where there is a genuine possibility for fuel substitution. Figure 3.1 illustrates the relationship between the pricing signals sent to the consumers by the administered prices and the relative economic costs of the different fuels if used for cooking. It shows that electricity has the highest economic cost of all fuels, followed by natural gas. But while all other fuels are priced at their full economic cost, the financial price is below the economic cost for electricity and for natural gas. The financial price still makes electricity the most expensive fuel, but natural gas is the cheapest fuel for cooking. The relevance of this ratio has to be related to the role which each fuel plays within the Government's strategy for household fuel supply.

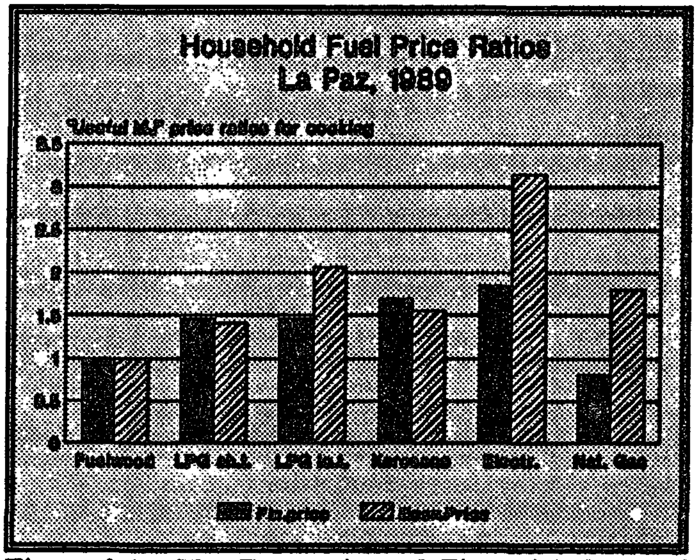

Figure 3.1: The Economic and Financial Costs of Fuels for Cooking

B. Fuelwood

3.2 Fuelwood is used as a fuel by less than 10% of the urban households and in a few artisanal production activities like the production of chiche and some bakeries. About half of the urban fuelwood consumers collect their own fuelwood; the other half obtain it from commercial supplies. The Government has no interventionist policy for this sector, and there is no need for it. Fuelwood is being eliminated from the urban market as a cooking fuel in spite of being the cheapest source of supply apart from natural gas. 5/

5/ Fuelwood is not a homogenous product like the other fuels. Therefore, fuelwood prices are less transparent than for other fuels. Prices vary between regions and within urban market places. ESMAP financed data work for this project found prices varying from US$ 3.6/GJ to US$ 8.5/GJ. No specific causal factors explain the variation. Therefore, estimates of fuelwood prices are estimates.

C. Electricity

3.3 Electricity is promoted for its application in uses other than cooking. But in spite of its price, the comfort of electricity has carved a niche on the high income end of the market as a fuel for cooking. The high share of urban electrified consumers (the highest percentage of non-connected urban consumers in the cities is found in Trinidad with 15%) is testimony to the high priority given to urban electrification by the Bolivian authorities. The vast majority of household electricity is supplied by the distribution companies that are connected to the interconnected national system, i.e., COBEE (North), ELFEC and ELFEO (Center), CRE (East), CESSA and CEPSA (South). The remaining urban electrified households are served by isolated systems handled by either ENDE or local cooperative companies. The granting of licenses for generation and transmission is a responsibility of the Ministry of Energy and Hydrocarbons (MEH), while licensing for distribution is a responsibility of the municipalities. However, the major control instruments such as pricing policies and electricity service regulations are outside the jurisdiction of the municipality; the MEH is responsible for pricing and distribution.

3.4 Electricity tariffs are regulated by the Electricity Code. It specifies that the price setting functions are a responsibility of DINE (Direccion Nacional de Electricidad of the MEH). According to the Code, tariffs should be set at a level that allows recouping of costs plus a 9% rate of return on the rate base. 6/ In practice, the application of this financial approach has led to a structure of tariffs, where:

(a) The average tariff received by the power companies is below long-run marginal cost, but covers the financial cost of production.

(b) The Plan Nacional de Energia estimated the economic price for household electricity (its long term average cost) at US$ 0.069 per kWh. The price paid by households in La Paz is about 56%, and the payment received by COBEE about 45% of the economic price.

(c) Household power consumption is being subsidized by industrial and commercial consumers. In the case of La Paz, which is supplied by COBEE, the average residential tariff in 1989 could barely cover the marginal distribution costs. 7/

(d) The subsidies to household consumption are not targeted at low-income consumers, they mainly benefit the higher-income groups. The reason is that the "lifeline tariff" concept is not applied. Consumers pay a fixed monthly charge for the first 50 kWh of consumption. The progression in the tariffs for consumption beyond this level

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6/ The Code allows to cover the following costs: operations; maintenance and management costs; depreciation on tangible assets; taxes; a 9% rate of return on the rate base.

7/ See ESMAP, La Paz Private Power Technical Assistance, February 1990.

of consumption is very low: the household tariffs charged by COBEE range from 0.066 to 0.075 Bs./kWh (US$ 0.0257 to 0.0292). [8/] Since households in the lowest income quintile consume less than 50 kWhs on average, the overall result of the tariff structure is that average cost per kWh of consumption is higher for low level consumers than for high level consumers.

(e) Taxes make up about a quarter of the average price (fixed charge plus tariff plus taxes) of monthly kWh consumption.

3.5 The Government currently is undertaking a review of both the LRMC and the electricity tariff to have these reflect economic cost.

3.6 The cross-subsidy of household consumption by industrial and commercial consumers is defended by supporters on social welfare grounds. But it is doubtful whether the present structure of tariffs in Bolivia makes a positive contribution to the achievement of equity goals. The basic equity issue in Bolivian household electricity consumption is the lack of access to electricity by a majority of the population. The satisfaction of the needs of this population should be the immediate social concern. Their prospects for gaining access to electricity will to a large degree depend on the availability of finance for grid expansion and power capacity. Subsidies to electricity consumption reduce the availability of finance. Secondly, while electricity for lighting is a basic need in a modern society, there is no social justification to subsidize the consumption of electricity for household appliances as well. This, however, is the case in COBEE's area of service. For reasons of both efficiency and revenue-raising, the Government should limit subsidies only to low-income households.

D. Hydrocarbons

3.7 Petroleum product prices are regulated by the DGH, the Direccion General de Hidrocarburos. From the 1960s until the mid-1980s, petroleum product prices, in particular transport fuels, were usually subsidized. With the new economic policy of 1985, economic cost pricing has been established as the basic principle for the pricing of petroleum fuels, although its still not being applied.

Kerosene

3.8 Kerosene is distributed to households through subsidiaries of YPFB (the source of supply for 82% of kerosene-consuming households), local agencies, shops (9% of kerosene-consuming households that normally live in minor urban centers not served by a YPFB subsidiary), sales from trucks, and in exceptional cases, through distribution contracts which YPFB signs with municipalities.

8/ Due to the low cost of COBEE's hydropower supplies, these tariffs are the lowest in Bolivia.

3.9 The policy of the Government is to restrict the household consumption of kerosene in order to facilitate control of its use as a solvent in cocaine processing. The pricing policy supports the Government objective of demand restraint. The economic price of kerosene can be defined as the international price of kerosene plus shipping, freight and distribution costs. As such the "Plan Nacional de Energia" in 1990 calculated it at US$ 29.2/bbl or 0.55 bs per liter, which is very close to the actual consumer price.

LPG

3.10 Except for a short period during the mid-1980s, the domestic production of LPG has been larger than domestic demand for the last three decades. Government policy has therefore supported the growth in the domestic market of the LPG. The domestic LPG infrastructure is excellent, a fact which has propelled LPG into the number one fuel for urban households in terms of overall penetration and toe. LPG is obtained from the two refineries in Cochabamba and in Santa Cruz and from four natural gas extraction plants. A well-developed LPG liquid pipeline system connects all the major supply sources to 11 primary depots/bottling plants located in the larger population areas. These depots are used as transhipment sources for a network of smaller, secondary bulk depots. Both the primary and secondary depots serve larger industrial/commercial clients directly by bulk road tanker. They also have bottling plants which fill 10 kg cylinders for distribution to agents and direct household customers.

3.11 The system of production and distribution is well organized with only some minor problems. The LPG production, supply, storage and bottling facilities are wholly-owned and operated by YPFB. But as part of the privatization drive in Bolivia, private operators are encouraged to invest in bottling plants as well. Cylinder distribution is almost totally in the hands of private licensed distributors, which sell directly from trucks to the household customers. The largest number of distributors is found in Santa Cruz where 10 companies operate. The urban centers are divided up into supply areas each with an agreed upon routes corresponding to the number of distributors. The areas rotate among the distributors on a monthly basis. This system makes it possible to identify the responsibility of supply in times of scarcity and makes it possible for households to compare the level of quality of service provided by the different distributors. 2/

3.12 Each distributor receives a five-year operating contract provided they maintain a specified minimum infrastructure (cylinders, offices, insurance, equipment, vehicles). This ensures a certain safety of both supply and of operations. Safety is also supported by a non-bureaucratic system of replacing worn out cylinders: the margin for the distributor includes payment for the acquisition of 8 new cylinders per 1000 sold cylinders. At the end of each month, the distributor is obliged to hand over to YPFB the number of new cylinders that corresponds to his sales. A weak

2/ This system was conceived in response to the crisis of scarcity which evolved in the beginning of the 1980s, when LPG was supplied through stores. As supply was lower than demand, LPG bottles were siphoned off to a black market. Since it was difficult to identify the source of manipulation in the then system, it was replaced with the present structure.

spot in the infrastructure is that the number of controllers is too small to effectively protect the households against cheating with the LPG content in the cylinders.

3.13 The key policy issue for the 1990s is to define a strategy to deal with the coming LPG demand/supply gap, see Figure 3.2. Urban and total demand growth for LPG is expected to be lower in the 1990s than during the previous two decades. But unless new oil and gas fields are discovered and developed, demand will outstrip supply before the end of the decade even under the most optimistic of the present supply scenarios. This scenario calls for an active policy to promote more efficient use of LPG through the diffusion of improved LPG stoves and to inform households on how to economize cooking practices. The implication for LPG pricing is ambiguous. In the medium term, there is an exportable surplus of LPG on the market; at the end of the 1990s, LPG will have to be imported. The medium-term economic cost of LPG is lower than the long-run economic cost. In the short term, the relevant opportunity cost of increased LPG consumption is the netback price of LPG exports to Chile plus the internal costs of distribution. In the long run, the economic cost of LPG will be equivalent to the cost of imports plus the costs of distribution. The two price structures for LPG are shown in Table 3.1.

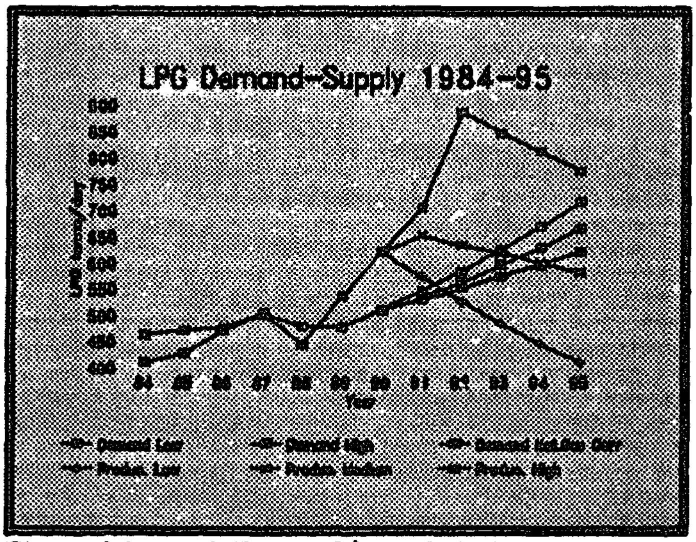

Figure 3.2: LPG Demand/Supply Balance

3.14 The November 1990 price revision led to a financial price of LPG (Bs. 0.85/kg) that is higher than the short term economic price (bs. 0.73/kg) but lower than the long-term economic price (Bs. 1.06/kg). This is a sensible policy for the transition period.

Table 3.1: LPG Price Structure

November 1990 LPG Price Structure (US$)/ton

		imported	exported
US LPG (FOB)	:	135	
Freight to Arica	:	30	
Arica - La Paz	:	80 **	185 *
Internal Depot	:	20	-23
Bottling	:	20	20
Distribution	:	59	59
Economic Price	:	344	241
Bs/kg	:	1.06	0.73
Consumer price	:	0.85	0.85

* Export price cif Chile
** Freight cost La Paz to border
Source: Matthews & Calderon, LPG Distribution in Bolivia

Natural Gas Distribution to Households

3.15 Promoting natural gas as a substitute for LPG in the residential and commercial area is the key element in the present Government's demand strategy to address the scarcity crisis. Bolivia's natural gas transmission grid was originally conceived and constructed to supply bulk industrial customers and gas-fired power generation plants. It is now basically completed and reaches the city-gates of most large cities in Bolivia: La

Paz, Santa Cruz, Cochabamba, Sucre, Oruro, Potosi and Tarija. Natural gas is presently being supplied to 5 power plants (2 in Santa Cruz, 2 in Sucre, and 1 in Tarija) and 208 industrial customers (84 in Santa Cruz, 49 in La Paz, 32 in Cochabamba and the rest in Tarija, Sucre and Oruro). Residential and commercial markets are not yet developed, accounting only for 160 customers in Santa Cruz and 15 in Cochabamba.

3.16 In 1986, the Government instructed YPFB to transfer natural gas distribution responsibilities to the private sector. As a result distribution companies were formed, with YPFB and other local institutions as shareholders, in Santa Cruz, Cochabamba, Sucre and Tarija (respectively SERGAS, EMCOGAS, EMDIGAS and ENTAGAS). The Ministry of Energy and Hydrocarbons and YPFB are concerned about the technical experience and financial means of these distribution companies and a work is being undertaken with World Bank assistance to identify the best means to implement a program for natural gas distribution.

3.17 Prices of natural gas are set by ministerial decree. Prices are based on historical levels and are not supported by cost of service studies, nor do they include a depletion allowance. They are changed, periodically, usually following fluctuations in the US$/Bs. exchange rate. Existing distribution companies sell only to industrial customers. But a price of US$ 3.3/MCF has been set for residential and commercial consumers. The household natural gas price is substantially below the average cost of natural gas supply to the end-residential consumer of US$ 6.3, according to the price structure shown in Table 3.2. Adding customer investment in installations and connection, the average cost per MCF of residential consumption rises to US$ 7.3. However, because of the high share of fixed investment costs in the total cost of natural gas supply, the marginal cost of incremental gas consumption is much lower. In theory, the heavy subsidy makes natural gas the cheapest fuel to the residential consumer, if it were available. However, the commercial viability of natural gas distribution to the domestic and commercial sector will depend on a solution to price competitiveness of natural gas if natural gas prices are to cover the full financial cost of supply which is twice as high as the present authorized price of natural gas for households. The situation is analyzed in Table 3.2 and Figure 3.1.

E. Government Policy: Non-price Measures to Promote Energy Savings in Urban Households

3.18 So far, the Government has not launched any energy saving campaigns. The institutional infrastructure for doing so was too weak. The one exception is a program to distribute energy-saving light bulbs donated by the Dutch Government through ENDE. The light bulbs were sold at highly subsidized prices to household customers at ENDE billing offices. About half of the 200,000 light bulbs have been sold during the last four years. Unless the light bulbs continue to be subsidized by foreign governments, the

Table 3.2: Natural Gas Structure

Residential and Commercial (US$/MCF)

City-gate price:	1.77
Distribution Costs:	4.54
Total supply cost:	6.31
(present price = 3.3)	
Customer Investment:	0.99
Total consumer cost:	7.30

Source: ESMAP 1991 Natural Gas report on Bolivia program has no immediate future in Bolivia: the economic cost of the light bulbs relative to the economic cost of electricity supply is too high to provide an attractive rate of return.

3.19 In the medium-term, it will be more cost-effective to base energy-saving campaigns on awareness-raising campaigns in schools and through television, radio and newspapers.

3.20 An additional policy for the longer term would be to introduce norms for energy consumption for household appliances and to establish a institutional framework that can ensure its application in practice. At present, the situation is not yet mature for this policy as a substantial black market for smuggled imported goods is still in operation in spite of the drastic reduction in import tariffs to 10%. The prospects may improve as more competition is introduced into the oligopolistic commercial import market and leads to a lowering of prices that makes black market operations increasingly unattractive.

IV. GOVERNMENT POLICY FOR RURAL ENERGY

A. The Rural Economy

4.1 In 1988, agriculture accounted for about 22% of GDP; another 20% of GDP originated from related economic activities. The rural population (persons living in agglomerations of less than 2000 inhabitants) in 1989 amounted to 3.7 million, of which 3.4 million were members of peasant families. Rural energy demand is overwhelmingly based on the consumption of biomass fuels and mainly composed of household energy demand.

> In national energy balances, rural household energy consumption is mixed with urban household energy consumption under the item "household and residential" energy demand. "Rural energy" demand in the national energy balance refers to the productive energy demand; and includes only the explicit part of this demand - the consumption of fuels. The implicit energy consumption of draft animal power is not included in the statistics. Unless other wise stated, in this report, the term "rural energy" is used for both household and productive rural energy demand.

4.2 Rural household energy demand accounts for 28% and rural productive energy demand accounts for less than 5% of national energy consumption. The total rural consumption of modern fuels (hydrocarbons and electricity) amounts to only 2% of the national demand for commercial fuels.

4.3 The rural economy is very heterogenous. This is one of the reasons why it has been difficult to define an optimal national policy for the sector. Basically, rural households can be classified by a matrix consisting of six blocks based on two criteria: the geography/climate--three regions; and the size/commercial orientation of the farmer which divides farmers into two categories--the 550,000 "campesino farmers" who produce mostly for own consumption, and the 40,000 "commercial farmers" who produce mostly for sales. [10/]

(a) 51% of the rural population, or about 300,000 households live in the Altiplano. Difficult climatic conditions including droughts and frost limit agricultural potential. Soil is severely exhausted by extensive use, and, in any given year, two-thirds of the land has to be kept idle to allow soils to regenerate. Farmers are almost exclusively "campesinos", who cultivate low-productivity small farms to produce staples and

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10/ All campesinos are related to the market, as they depend on it for goods such as sugar, salt and cooking oil. But campesino households should be further subdivided into two major groups for analytical purposes. First, those households who do not produce enough food to sustain themselves; and second, those that, while poor, have a small production surplus which could be expanded. For the first, few "productive" projects can be identified; help to them has to be given through "social" projects, such as the creation of employment through labor intensive infrastructure projects. About one third of the campesinos belong to this category.

vegetables (potatoes, maize, beans, quinua, etc.). They have poor links to markets and credit institutions and sell, on average, less than 30% of their output.

(b) 31% of the rural population, or about 190,000 households live in the Valleys. Despite the low productivity levels, relatively favorable weather and soil conditions allow two-crop farming in the region. The mostly campesino farmers are engaged in cash crop production, including fruits, flowers, and timber as well as dairy farming. The largest obstacle to raise agricultural productivity is poor market access, partly resulting from poor transport.

(c) 18% of the rural population, or about 110,000 households live in the Lowlands. This is the most dynamic region for commercial agriculture. The average landholding of the farmers is much larger than those of the other two regions, but recent migrants in the newly settled areas ("los colonos") can often only use 1-2 hectares and have no title to their land. Major crops grown are sugar, rice, cotton, soybeans, and oilseeds. Some of the production is exported, most is sold in urban markets locally as well as in the Altiplano. Large-scale, extensive cattle farms are found in the northern areas.

4.4 The total area under cultivation (not including pastures and fallows) is estimated at about 2.3 million hectares, of which the "campesino farmers" cultivate 2.2 million hectares. The "campesinos" grow about 70% of the food which is consumed in Bolivia; the rest is covered by imports and by the production of "commercial" farmers. Food security is becoming a concern as the production of food per inhabitant is falling. During the 1980s, the cultivated area expanded by only 150,000 hectares (6.5% in total or 0.5% per year) while production per hectare stagnated or declined due to drought and over-exploitation of the resource base.

4.5 This development has lead to a reevaluation of the approach to agricultural development in Bolivia. During the 1970s, the national strategy for agricultural development was export oriented and focused on "commercial agriculture" in the Lowlands. As Bolivia did not have a natural competitive advantage in the crops such as cotton, sugar and soya, this development was heavily subsidized. The limits to this approach became apparent through the failure of finding profitable market outlets for the export production and through the rising cost of the food import bill.

4.6 The definition of an appropriate national policy strategy for the rural sector is a difficult task. From a purely technical/economic point of view, an appropriate balance has to be found in three interlinked areas:

(a) The promotion of export crops as well as of domestic food production, respectively.

(b) Interventions in support of "campesino farmers" and "commercial farmers."

(c) The allocation of resources to promote farming between the three major geographic/climatic regions.

4.7 To determine the "correct" technical/economic choice for the three issues is already a daunting task. But in addition, the strategy must balance economic considerations against welfare and regional policy objectives. Ninety five percent of the poorest 30% of Bolivian households are found among the "campesino farmers." Activities in their support are related to poverty alleviation and have regional implications. In the Altiplano and the Valleys, 61% of the farmers own land smaller than 5 hectares; in the Lowlands 84% of the farmers own more than 5 hectares.

4.8 The difficulty of defining an appropriate policy at the macro level has two important implications for policy-makers. First and foremost, the situation makes it particularly important to base project selection on sound microeconomic criteria. Secondly, project identification has to take place at micro-regional level. The derived operational challenge is to find a means of reconciling this micro-based approach with the need to balance the different national objectives.

B. Socio-Economic Determinants of Rural Household Energy Consumption

Rural Levels of Income

4.9 The average income per capita of US$ 250 in rural Bolivia is lower than the average income in urban areas. For instance, La Paz has an average income per capita of US$ 855. Contrary to popular belief, the reliance of the rural population on woodfuels has more to do with the low level of income of the rural population than with the ample availability of "free" biomass in rural areas. As rural families move up the income ladder, they shift their consumption increasingly to modern fuels. The rural share of modern fuels is low because the average rural income is low. In addition, the size of the rural market for modern forms of energy is reduced because the distribution of rural incomes is as

Table 4.1: Rural Family Incomes and Debt Capacity
Year: 1989

Condition	Number of families (1000)	Aver. Inc. per person US$	Aver. House-hold income US$	Amort./ income ratio	Annual amort. capacity, US$	Total Debt capacity US$ *)
Extr. poor	131	90	505	0.05	25	125
Very poor	197	160	900	0.10	90	450
Poor	131	250	1,400	0.15	160	800
Middle	131	450	2,500	0.20	500	2,500
Rich	53	3,000	16,650	0.35	6,000	30,000
Very rich	13	25,000	140,300	0.35	50,000	243,000
TOTAL	656	250				

* Assuming that an investment loan has to be repaid over 7 years at 10% interest. Source for income figures: Calvin Miller, Evaluacion del Credito Rural en Bolivia, ESMAP/MEH, June 1990.

skewed as the urban incomes: the three categories of rural poor who in Table 4.1 make up 70% of the rural families have a 12% share of rural income (see Figure 4.1), the richest 2% dispose of 51% of total rural income.

4.10 The level of income is a major determinant for the market of any energy technology. It determines the cash flow for "petty" investments like LPG stoves and the debt capacity or annual amortization capacity for "major" investments like the household connection to a rural electricity grid or the purchase of a water pump for irrigation. Only a minority of rural households has an income which is high enough to allow these expenditures in light of other priority demands. Based on an estimate of the maximum savings capacity for each income category of household, it can be concluded that the range of technological options that can be offered to the three lowest income groups (70% of the rural population) is very limited. The debt capacity of this population is between US$ 125 and US$ 1,700. Since other needs than energy have to be attended, only energy technologies that cost a fraction of this amount (perhaps a fourth) can find a market to this section of the rural population. That is, relevant **energy technologies have to be in the US$ 30 to 400 range.**

Local Availability of Biomass

4.11 The use of biomass energy for cooking, and of kerosene and of candles for lighting, accounts for more than 90% of total rural household energy consumption and some 20% of national energy consumption. **Charcoal** is hardly consumed in rural areas. In all three regions, the biomass fuels are collected by women and children, with men playing a subsidiary function of principally tree cutting. The local fuel mix is determined by the availability of the local biomass energy resources, fuelwood, dung, stalks and roots. The consumption of **fuelwood** makes up about three-fourths of the biomass consumption for cooking, **dung** covers the remaining need.

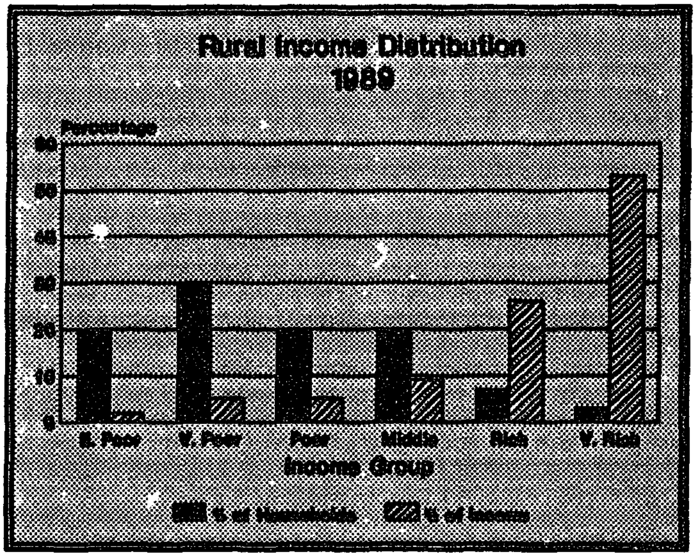

Figure 4.1: Rural Income Distribution

C. The Structure of Rural Household Fuel Consumption

Consumption of Dung for Cooking

4.12 The consumption of some 550,000 tons of dung for energy purposes (120,000 toe) covers about 20% of rural energy demand. The bulk of this is used by households as a fuel for cooking. Dung is the least attractive fuel for cooking. It is used in areas where farmers have cows and where fuelwood is scarce, as in extensive regions of the Altiplano. A relatively important percentage of dung for fuel is commercialized, and either sold to rural industries or to rural households.

Fuelwood

4.13 The consumption of fuelwood per capita in the rural households is correlated with the availability of fuelwood; it is highest in the Lowlands, and lowest in the Altiplano. **The average number of man-days per month spent by a household on fuel collection is 1.7 in the Altiplano, 1.2 in the Valleys and 1.0 in the Lowlands.** Since fuelwood collection is normally done in connection with the guarding of grazing animals, the households perceive the opportunity cost of these collection times as close to zero.

4.14 In view of the huge differences in the **regional availability of wooden resources per hectare per inhabitant** (see Table 4.2) the interregional differences in the time used for fuelwood collection are surprisingly small. Forests cover most of the land in the lowlands, whereas the Altiplano is practically totally denuded by forests. Fuelwood in the Altiplano is obtained from the "thola," a shrub which can reach some two meters, but is normally cut when it is not taller than 40 cms. Yet, on the whole, Altiplano households do not perceive that there is a problem of fuelwood scarcity, and where fuelwood is scarce, dung is used as a fuel for cooking. Although fuelwood is more widely available in Santa Cruz and in the Beni provinces, the habit of purchasing fuelwood is more widespread in these two provinces than in the Altiplano and in the Valleys [11/].

Table 4.2: Woodfuel Resources in Bolivia

Woodfuel Potential, 1990

	Surface km^2	Standing stock (1000 tons)	TOE (1000)	An. Growth, tons/ha biomass	wood
Altiplano					
Pastures and shrubs	93,000	22,000	1,834		
Forests	2,515	13,218	5,659	0-10	0-3
Valleys					
Pastures and shrubs	59,000	88,000	11,800		
Forests	109,000	709,000	290,000	7-15	3-4
Lowlands					
Pastures and shrubs	189,000	720,000	150,000		
Forests	408,000	3,185,000	1,500,000	10-25	4-9
TOTAL	863,000	4,737,000	1,959,293		

Source: Oscar von Borries, Reforestacion en el Altiplano, Valles, y otras areas afectadas por la deforestacion en la produccio de lena y carbon, October 1990, project report

4.15 **Intraregional differences** in fuelwood collection are larger. In some local areas, fuelwood scarcity is a real and perceived problem. One of the most affected areas is Yamparaez

11/ This may have to do with the fact, that a wider availability of fuelwood facilitates not only autocollection but, in particular, the commercial collection of fuelwood. The "supply" factor thus seems to outweigh the "demand" factor.

in the Province of Chuquisaca where households use 2 man-days per week for fuelwood connection.

4.16 Local scarcities of fuelwood are expected to become more common in the future as an estimated 30 to 40% of Bolivian territory is affected by erosion to some extent. Erosion is caused by inadequate agricultural practices, which again are a consequence of the pressure of a growing population on scarce arable land. While fuelwood collection plays an insignificant role in erosion, **deforestation** reduces the availability of fuelwood supplies. Over the last 20 years more than 4 million has have been deforested -- annual deforestation is estimated at 800 hectares in the Altiplano, 43,000 hectares in the Valleys, and 270,000 hectares in the Lowlands.

Kerosene

4.17 Kerosene is used by rural households as the most important fuel for lighting, and as an important fuel for cooking. Kerosene is purchased by the campesinos in local shops. Price is correlated with distance from the urban centers of supply, and with the quality of the road. While urban prices in 1990 were around 0.8 Bs. (US$ 0.24) per liter, in the more distant rural centers, the price climbed to 1.50 Bs. (US$ 0.45) per liter.

4.18 The consumption by rural households is low, in the range of 1-5 liters per month. Because of the anti-cocaine policy of the Government, there are no possibilities for an expansion of the role of kerosene as a substitute fuel for fuelwood in cooking.

LPG

4.19 Unless a farm household is too poor to afford it, LPG is the preferred fuel for cooking in rural areas. Acquisition of an LPG stove is typically the first consumer good investment in rural areas after improved roofs. LPG cookers are found in about 50% of rural households, and 16% of rural households use LPG as the primary fuel [12/]. In fuelwood scarce areas, households begin to switch to LPG out of necessity. On the whole, however, LPG is used for its convenience as a supplementary fuel to fuelwood, used for minor meals and when the wood is wet. In addition, some use is made of LPG for lighting. Principal rural users of LPG consume about 10 kg per household and per month, secondary LPG users average 2 kgs. The consumption of the 340,000 rural LPG-consuming households amounted in 1990 to about 15,000 tons, or about 8% of total LPG consumption in Bolivia.

Extent of Rural Electrification

4.20 Less than 10% of rural households in the Altiplano and 20% of rural households in the Valleys consume electricity. The coverage in the Lowlands is more difficult to estimate, but is likely to be similar to the percentage in the Valleys. The penetration of electricity in rural Bolivia

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12/ Estimates based on field visits of the ESMAP/MEH LPG consultants Matthews and Calderon. These figures have to be revised once the ESMAP/INE Energy Survey has been processed.

is low because of supply-side and demand-side factors. On the **supply side**, a constraint to increased penetration is the high cost of rural electrification projects that ranges from US$ 750 to US$ 1,700 per connected household for relevant rural projects [13]. On the **demand side**, the constraint is the low level of rural household demand, i.e., the low level of capacity to pay for connections and the low level of productive demand for power. Typically, productive rural demand is 20% of the total demand in rural electrification projects.

D. Rural Productive Demand for Energy

4.21 The **productive demand for energy in rural Bolivia** comes from farming (energy for irrigation, plowing, etc.), processing of agricultural products, from agro-industries and from artisanal and service industries. Although electricity can be used for water pumping in irrigation projects, it is used only in the transformation of agricultural products.

Productive Demand in Agriculture

4.22 **"Campesino" farming** is a labor and draft-animal intensive activity with few demands for fuels. Energy demand is minimal and will continue to be so. During the 1990s the potential for energy using activity is in expansion of irrigation, potable water pumping for household and animal needs and in the drying of crops. In addition, some demand for energy will come from small scale processing of farm products, such as coffee.

4.23 The **commercial farmers** make up less than 10% of rural farmers and account for more than 90% of total rural energy consumption. The sugar industry is the single most important rural consumer of energy, based mainly on the combustion of bagasse (see Annex IV). The approximately 7,000 tractors that are found in Bolivia account for most of the rural productive demand for petroleum fuels. Of these, the majority are found in commercial farming.

Energy Demand in Rural Industries

4.24 Field studies of the most important energy-consuming industries--the limestone industry, the gypsum industry, the brick and tile industry, and chicha production (an alcoholic drink)--showed that expenditures on energy added up to more than 30% of total costs in all industries, except for the small chicha breweries where energy costs are only 8 - 12% of the turnover (see Annex V).

4.25 Fuel use is variable as the kilns can easily be adapted for use with different fuels. The limestone industry uses gas, dung, fuelwood or dung; the gypsum industry rely on fuelwood or

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13/ According to the 1991 World Bank report, Maintenance Neglect in the Power Sector: The costs and options to overcome it, the investment costs in generation, transmission and distribution is US$ 1,750 in average (combined rural and urban) for Latin American countries to increment one kW of capacity.

gas and some gasoline for milling; the brick and tile industry use woodfuels, heavy fuel oil or natural gas. The local availability of fuels and the relative price of the fuels seem to be equally important determinants for fuel choice.

4.26 Fuel consumption in these industries can be reduced by between 18 to 30% by insulation of the kilns. A program to insulate the kilns should be feasible: the savings are sufficiently large to interest the individual entrepreneurs and the relative few number of establishments makes it easy to reach the target group. A program should leave out small-scale operations, where the kilns are fired only one to five times a year. Investments in these will not prove to be cost-effective.

4.27 The scope for improvements in chicha breweries is small. Energy cost is a small fraction of turnover, and the producers will, therefore, not be much motivated to invest in improved stoves. Some savings can be gained, however, by promoting improved cooking habits, e.g., using lids, reducing the fire once the boiling point is reached.

4.28 Ninety percent of the charcoal produced in Bolivia is used in the smelting plant ENAF in Oruro. Charcoal production takes place mainly in the Chaco, from where it is shipped by train via Argentina to Oruro. Due to the quality control by ENAF, producers have invested in high-yielding charcoal kilns. No energy-saving program is likely to have any impact under these circumstances.

E. Rural Energy Policy and Investments

4.29 During the last two decades, the domestic orientation of the MEH's policy has focused on urban energy needs. As a result an explicit energy policy for the rural population is still missing. The absence of a rural energy policy had two consequences. First, with no overall policy to guide development, there was no mechanism for evaluating potential projects and for balancing the energy needs of the various rural population centers. The result is that the rural energy sector is an uncoordinated area where each institution acts without any coherent strategy. Coordination of rural electrification planning is virtually nonexistent between COFER (the agency nominally responsible for rural electrification), the MEH and other ministries responsible for rural development, such as MACA. The RDCs submit yearly plans to the Ministry of Planning for rural projects; the energy components of these are rarely coordinated with COFER, ENDE or the MEH. Similarly, cooperation between RDCs and NGOs engaged in rural development has been spotty. For the most part, NGO as well as bilateral work in rural energy projects have lacked any type of national/regional coordination. Thus, rural energy project implementation mostly depends on financial opportunities, social pressures, political interests or personal ideas. Frequently the projects are only partially implemented or soon left to collapse, while efforts concentrate on new and unconnected projects.

4.30 Second, partly due to inattention to the needs of the rural population, and in part due to the "self-collected fuel" character of rural energy, the scope of the public investments in rural energy has been modest. Annual investments in rural electrification projects in Bolivia have been between US$ 5 - 10 million in each of the years 1988 and 1989. 14/ In addition, there have been some public investment in geothermal energy in Potosi, and also some small public investments in what is termed "non-conventional" energy. Altogether these investments amount to approximately US$ 0.4 million per year. The public energy investment per inhabitant in the rural area is US$ 1 - 3 per annum. The majority of this investment has been made in the 5 - 10% of the rural area which is already under the process of electrification. Almost no energy investments were made in other areas.

4.31 In addition, some investments are channelled to energy projects by NGOs that operate in rural areas. Foreign donors channel an estimated US$ 70 - 100 million to projects through NGOs, some of which is energy-related. How much is unknown, but it is likely that it amounts to no more than US$5 million per year. Finally, investments made by electrification cooperatives are not counted as public investments, and, therefore, have to be added as well. All in all, rural energy investments during the second half of the 1980s have amounted to less than US$ 15 million per year, or less than US$ 4 per rural inhabitant.

4.32 The overall result of the institutional situation is: (i) under-investment in rural energy needs, and (ii) a lack of demand-driven orientation. Successful rural programs are carried out by institutions which provide services in response to soundly assessed demand. This contradicts the supply-driven policies of many service organizations which try to induce clients to consume that which is judged best for them. Since the needs of the rural population have to attract more attention by the MEH during the 1990s for obvious equity reasons, the MEH has to define what the key needs of the rural population are, and which institutional issues have to be addressed as a matter of priority.

14/ This amount includes only public investment in electricity projects, i.e. investments performed by companies which have at least 50% public ownership. No amounts relating to the investments of "private" electricity cooperatives are documented.

V. POLICY AND INSTITUTIONAL ISSUES IN RURAL ENERGY

5.1 The key policy issues to address in rural energy are: (i) the welfare consequences of the use of biofuels as the main source for cooking; (ii) the welfare consequences of the low penetration of electricity in rural areas; and (iii) least-cost options to cover the productive use of energy.

A. The Welfare Implications of an Increased Consumption of Biomass Fuels

5.2 Modern fuels are preferred by rural consumers, but the lack of affordability leads to a continued reliance on biomass fuels. According to forecasts made by the "Plan Nacional de Energia" in 1990, both fuelwood and dung demand in Bolivia are expected to grow by about 15% up to the year 2000. The growth in demand has two welfare consequences. First, it is expected that the scarcity of fuelwood will become more pronounced during the 1990s as an estimated 30 to 40% of Bolivian territory is to some extent affected by erosion. This will lead to an increase in the time used on fuelwood collection. Second, the consumption of fuelwood and of dung for energy uses will have some negative consequences for agricultural soils and affect agricultural productivity.

5.3 There are three options that can ensure a better long-term compatibility between fuelwood supply and demand: (i) promotion of fuelwood savings through more efficient stove and pot designs; (ii) fuelwood substitution by LPG [15/]; and (iii) increased woodfuel supply through reforestation and forest management projects. The promotion of LPG has a negative impact on the balance of payments; the other two options have a high degree of uncertainty attached to the expected results of their promotion.

Diffusion of Improved Household Biomass Stoves

5.4 Rural stoves in Bolivia are self-constructed stoves made out of either clay or scrap metal. A few ceramic stoves are sold in the markets in the Altiplano and the Valleys. ESMAP tests have shown that the efficiency of the most common stoves is low and that substantial savings can be achieved through better designs. An improved ceramic model designed by the ESMAP project and built by ceramic craftsmen for a market cost of 10 Bs. (US$ 3) showed energy savings of 50% in the laboratory. In practical household use, the achievable savings from a switch to the improved stove are probably half the amount.

5.5 Previous attempts at promoting improved fuelwood stoves in Chuquisaca failed (see Annex VI). The model, a Lorena-type stove, was technically and economically inadequate. This

15/ Kerosene is an other potentially interesting option. Some rural households use kerosene cookers in addition to kerosene lamps. But the anti-cocaine policy of the Government attempts to limit the consumption of kerosene for any purpose.

disappointment repeats the worldwide experience with the diffusion of improved fuelwood stoves for rural areas. As long as fuelwood is a "free" good, which is not difficult to obtain, and the improved stoves offer no user-advantages beyond energy savings, it is difficult for diffusion programs to achieve lasting results.

5.6 An alternative approach, with greater chances of success is to **promote low cost improved kitchens where the improved ceramic stove is part of the overall design.** Field investigations of the ESMAP Bolivia Household Energy Project showed (i) that rural women expressed an interest in investing in a new stove if it provided a higher comfort, and (ii) that the kitchen area of Altiplano farm houses is usually rebuilt in three to four years intervals. Three different types of self-built kitchens were designed that offer substantial advantages in comfort over present practices with construction costs for the materials ranging from US$ 7 for the cheapest model to US$ 37 for the most expensive model (see Annex VI). The improved ceramic stove developed by ESMAP is a component in all three kitchen modules. It would be built by the traditional ceramic stove and pot makers after previous training in the method of production. The cost of production is estimated at 5 Bs. (US$ 1.6). The stove would be sold by the pot makers on the traditional rural markets.

5.7 No previous experience exists with this type of approach in rural areas, but the idea merits testing. A pilot area should be found where there is a scarcity of fuelwood. Here, the diffusion of the "improved kitchen design" should be tested by an experienced rural NGO during a two-year period. Based on the results of this pilot project, the MEH will be in a position to determine whether the promotion of improved rural stoves based on this concept has a future in Bolivia. If the results are positive, a "nationwide" campaign should be implemented.

5.8 The use of a **pressure cooker** provides particularly high energy savings in the Altiplano because of the high altitude, the low boiling temperature, and the decrease in cooking time with temperature. Since cooking times are also reduced, the diffusion of pressure stoves among households should be possible, provided that the prices are subsidized. Since pressure cookers are expensive (US$ 50), subsidies of at least 80% are needed to promote a large-scale diffusion in the Altiplano. This is a high cost; if all rural Altiplano households were to receive a pressure cooker, the cost of the subsidy would amount to US$ 12 million. But presumably this cost could be justified by the benefits from avoided degradation through their use. Therefore, a subsidized distribution of pressurized cookers should be tested alongside with the promotion of improved kitchens. The impact on consumer welfare and on fuel savings should be monitored to provide information on the level of benefits of such a program. If the benefits outweigh costs, a diffusion program at a larger scale can be launched.

Energy Savings in Rural Industries

5.9 Fuel consumption in the brick, tile, limestone and gypsum industries can be reduced by between 18 to 30% through insulating kilns. A program to insulate the kilns should be feasible: the savings are sufficiently large to interest the individual entrepreneurs, and the relative few number of establishments makes it easy to reach the target group. A program should leave out small-scale operations where the kilns are fired only one to five times a year. Investments in these will not prove to be cost-effective.

5.10 The scope for improvements in chicha breweries is small. Energy cost is a small fraction of turnover, and the producers will, therefore, not be motivated to invest in improved stoves. Some savings can be gained, however, by promoting improved cooking habits, e.g., using lids, and reducing the fire once the boiling point is reached.

Reforestation Projects

5.11 Reforestation activities in Bolivia have been few; successes even fewer (see Annex VII). The efforts of forestry agents in the Altiplano are frustrated by what they perceive as the farmer's non-interest in trees. FAO in 1990 launched a five-year "wood and energy" reforestation program in Bolivia with a budget of US$ 9.6 million. The problem with the activity is that the authorities have no reforestation concepts to rely on which have proven to be sustainable in Bolivia praxis.

> The conclusion that the proper response to rural fuelwood scarcity is to plant trees is too simple. Wood from natural forests or from cleared agricultural land is the cheapest fuel. But this is not the case with planted wood, either from firewood plantation or from village woodlots. Shortage of wood has to be analyzed not in absolute terms but in relative terms: there is a shortage of cheap wood! Although rural forestry projects offer the great advantage of relying on manpower that is theoretically abundant, its problems are not negligible. Often this type of intervention has been imposed on the peasants, thus addressing a problem identified by a planner rather than by the local population itself. This manifests itself in lack of interest on behalf of the rural population, which is compounded by the competition for land and labor with agriculture, and ill-adapted or inadequate extension services. Preferably a reforestation and/or management scheme should form an integrated part of a larger rural development project, such as anti-erosion/ productivity increase activities which provide the farmer with the hope of quick monetary income.

5.12 Until a viable reforestation scheme has been developed, MEH and MACA should not launch any new energy-forestation investment activities. The immediate priority for the two ministries is to start a project that attempts to develop a viable scheme. The ministries should cofinance an evaluation of past and present reforestation activities in Bolivia by an experienced team consisting of a forester, a forestry economist and a sociologist. Based on the findings of this evaluation which would need three to four months for field and other fact finding work, and one month for the drafting of the report, the two ministries will be in a position to evaluate the prospects for "wood and energy" programs in Bolivia.

Measures to Improve the Supply of LPG to Rural Areas [16/]

5.13 The development of the market for LPG can be left to the market forces:

(a) LPG distribution is a well-established commercial sector activity and the supply of LPG to the rural demand centers is relatively efficient. Ten kg cylinders are supplied from urban LPG bottling plants by truck to the rural agglomerations. Consumers purchase their supplies either directly from the trucks or from the local merchant store who sells LPG with a modest mark-up.

(b) Unlike the case of fuelwood and dung, no negative externalities are associated with the consumption of LPG.

5.14 The role of the MEH in rural LPG development can therefore be limited to defining an efficient framework for the functioning of the market forces and to monitor abuse of monopoly positions.

5.15 When judged from the need to develop a rural mass market for LPG during the 1990s, the present system has two weaknesses. First, the large distances from the urban LPG bottling plants involve economic costs because of an expensive transport of the tare weight of the bottle and a need for a large stock of cylinders. Second, the system is not geared to the cash-flow problems of the poorer farmers--whenever a cylinder is empty, the consumer needs to have more than Bs. 10 to replenish the supply. The question can be posed whether a more rational system can be established with lower costs and higher consumer convenience.

5.16 An alternative scheme for rural LPG distribution is to supply LPG in bulk to a series of rural networks consisting of small, simple storage and bottling stations that each serve a specific rural population center. The networks improve the stability of supply to the immediate areas. But also the surrounding areas should also benefit as small-scale informal distribution channels for LPG will be "spinned off" from the networks. Estimates from the project's rural LPG pre-feasibility study show that the scheme is economic, since the cost of investments in the small storage and bottling stations are more than counterbalanced by savings in transport costs and in cylinder investments, resulting in an economic rate of return of more than 10%. The financial rate of return of the investments for a private entrepreneur is slightly less as some of the economic savings are "external benefits" accrued by the households due to a lower need for households to have reserve cylinders.

5.17 The pre-feasibility study proposes to test this concept in a US$ 1 million pilot project for two networks in the Altiplano. Since the networks are to be operated by private entrepreneurs, most of the investment will be recuperated from the sale of the networks to private investors. If a donor can be found to finance the pilot project, a detailed feasibility study can be prepared for the two areas, after which an international call for tender can be issued for the equipment. Once

16/ For a more detailed discussion, see Annex III.

the results are known, a domestic call for tender can be published for the operation of each network through either leasing or acquisition.

B. The Welfare Implications of Rural Electrification

The Costs and the Market for Rural Electrification

5.18 The pattern of population settlement has obvious implications for the planning of "collective" energy systems like rural electrification projects. Some rural households live in such dispersed settlements that grid based electrification systems are not feasible. For those who live in villages the question for energy planners is whether the construction of an electricity grid for the village can be based on a connection to the national grid or whether an isolated grid should be built. As a rule of thumb in Bolivia, isolated grids are the most economic choice for communities that are situated more than 100 kms from the nearest national grid.

> In 1990, about 0.4 million rural inhabitants lived in villages, the other 3 million in dispersed settlements. In the Lowlands, one out of four peasants lives in a village, in the Altiplano, one out of 13.

5.19 The limits to rural electrification are defined by the balance between the cost of the projects and the benefits from rural electrification. As one moves from agglomerations that can be served through grid extension to agglomerations that have to be supplied from isolated grids and to the dispersed settlements, the cost for serving the markets increases [17/], while the population's capacity to pay for electricity services and their demand for electricity decreases:

(a) Farmers in the more populated rural areas have higher average incomes because they get better prices for their products. They are closer to the market and obtain their inputs at lower prices because of a better local infrastructure.

(b) Most of the productive demand for electricity comes from the service sector (see Table 6.6, Annex VIII). Since this depends on the level of rural income, the productive demand for electricity falls even more rapid than the household demand as one moves from the more to the less populated areas.

5.20 Providing electricity to an **additional 10% of rural households** by the year 2000 would demand an investment level of US$ 60 to 100 million (including the incremental cost of capacity expansion). Since the most profitable rural electrification projects were the first to be implemented, the cost of investment per connected household is increasing. Thus, each additional 10% of

17/ As long as the systems are compared at the same level of electricity quality. Stand alone PV systems, that can cover the demand for lighting and radio, but little more, can be obtained at about US$ 700, which is as low or lower than the cost of investment per connected household in grid based rural electrification projects.

penetration will demand substantially increasing resources and the financial cost of new rural electrification projects will quickly become prohibitive.

5.21 Full cost recovery would lead to rural electricity tariffs that are substantially higher than urban household tariffs. Although urban tariffs between regions/distribution companies are allowed to differ according to local cost conditions, it was thought that full cost rural tariffs would make electricity unaffordable to a majority of households. Therefore, typically, the investments in rural electrification are subsidized 30-40% often with foreign donor assistance. For the rural electrification projects in the 1990s, a continuation of this policy would imply **subsidies of US$ 300 to 500 per connected household**; and the payment of US$ 20-35 million in subsidies if another 10% of rural households are connected to new grids.

5.22 Where the acceptable balance is between the costs and the benefits if grid expansion is a question of political choice and of the overall availability of finance in the public sector. But based on rough estimates, the market for rural electrification projects can be split up into:

(a) areas, that can be supplied through grid extension (20-30% or rural population, or 130,000 to 200,000 rural households in the year 2000);

(b) areas, where rural households can be supplied by isolated grids (5-10% of rural population, or 30,000 to 65,000 households); and

(c) areas, where rural households live so dispersed that only individual systems are feasible (60-70% of the rural population, or 390,000 to 420,000 households).

5.23 From the above data, it can be concluded that the key **political issues** in rural electrification are: (i) whether the expansion of rural electrification can be justified by the benefits from electrification; (ii) whether equity is served by a policy which subsidizes the electricity consumption of the relatively more well-off farmers, while the poorer areas neither receive the benefits from electrification nor receive an equivalent amount of subsidies; and (iii) what the Government can do for the rural majority of the rural population that will not be served by electricity in the foreseeable future. The key **technical issues** are: (i) what the least cost options are for rural electrification; (ii) what the most appropriate planning and institutional framework is for rural electrification; and (iii) how initiatives can be organized to provide higher energy welfare to the population that is not served by electricity.

<u>Household Benefits from Rural Electrification</u> 18/

> The typical household in a rural electrification project consumes about 15 kWh per month. The electricity is used to power some 3 to 4 light bulbs and a radio. Radio and TV-users save money on batteries (car batteries or small batteries) that are a much more expensive source of energy. But most "base-line consumption" is [illegible]ghting. The introduction of electricity in a household leads to the replacement of alternative sources of lighting--kerosene lamps, LPG lamps, diesel lamps, gasoline lamps, candles. This has three effects on the consumers:
>
> (i) the cost of lighting normally decreases;
>
> (ii) the quality of lighting increases; and
>
> (iii) the quantity of lighting ("luminous flux" expressed in "lux") increases.
>
> The consumer benefits, therefore, comprise the economic/financial value of the cost of replaced fuel, plus the less tangible welfare benefits from the increased consumption of lighting in terms of quality and quantity, that give rise to a "consumer surplus."

5.24 The estimated marginal cost of rural electricity <u>consumed uniquely for cooking and lighting</u> are higher than those of kerosene and LPG based on the same end-use. These costs range from US¢12-37/kWh to US¢3-44/kWh respectively. While rural electrification can be difficult to justify financialy or economically whn oriented solely on household lighting and cooking, the viability of expanding the rural grid can be augmented if productive end-uses can be strengthened and/or developed (coupled with national tariff regimes). Usually the productive demand for power accounts for 30-50% of the demand for electricity in rural electrification projects. In the absence of a grid-based electrification project, most of the productive demand for electricity would be covered through standalone generators, albeit at a higher cost. Most of the household demand for electricity, on the other hand, will only be realized if a grid-based system is implemented. Therefore, the discussion below will focus on the household benefits from access to electrification. A household uses electricity for lighting and to power electrical appliances such as radios, TVs, and refrigerators. In most rural households the demand for lighting is usually limited to the satisfaction of basic lighting needs, i.e. for two to three light bulbs. This gives rise to a demand of 15 kWhs per month.

5.25 For household consumption higher than 15 kWh it is standard procedure to assume that the household benefits equal the financial cost plus the cost savings from the reduction in the consumption of batteries. The value of the benefits from the first 15 kWhs includes the financial cost of supply plus the value of fuel saving from substituting other lighting fuels plus the value of higher lighting levels and of higher user comfort. The value from electrification for basic lighting depend on the shape of the rural household demand curve for basic lighting service. <u>Table 5.1</u> pro-

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18/ See Annex IX for a more detailed methodological discussion.

vides an example of such a demand curve from the Asunta Valley households in the Yungas. 19/ In this non-electrified area, 30% of households used candles as their main source of lighting, 50% used kerosene wick lamps, and 20% LPG. LPG lamps provide a superior light than kerosene lamps, and the light from kerosene lamps is superior to the light from candles. As the households live in the same area, the relative use of fuels is not determined by fuel availability, but by demand factors. It is safe to assume that the richest households use LPG lamps and the poorest candles.

Table 5.1: Rural Household Demand for Lighting

Demand and Expenditures for Lighting in Asunta Valley, Yungas (average monthly figures per household)

Energy Source	Fuel expendit. US$/month	Consumption of light klmh	Price of lighting US$/klmh	Share of pre-electrification-consumers
Candles	6.75	3.54	1.71	30%
Kerosene	4.29	13.87	0.31	50%
Electricity	2.35	75.00	0.03	0%
LPG	1.94	96.75	0.02	20%

Source: UNDP/ESMAP, Rural Electrification and Demand Assessment in Asunta Valley, November 1990.

5.26 The relative use of lighting fuels in other regions will depend on the average level of rural income in the region and the quality of kerosene and LPG supply. What will not change is the disturbing result that the monthly cost of lighting in non-electrified rural areas is inversely related to household income and to the quantity (plus the non-shown quality) of lighting:

(a) The poorest households which rely on **candles** as their primary source of lighting have the lowest level of lighting consumption (as expressed in the volume of lux,lm), but the highest monthly expenditure on lighting. At the prevailing price for electricity in the project area, by switching to electricity, candle-using households can reduce their monthly fuel expenditures by two-thirds and increase their lighting consumption 25-fold.

(b) The "intermediate income" **consumers who use kerosene wick lamps** are able to enjoy a lighting consumption that is three to four times higher than the lighting consumption of candle consumers at two-thirds of the cost. By switching to electricity, kerosene consumers can reduce their monthly fuel costs by 40% and increase their lighting consumption five to six times.

(c) Compared to candle consumers, the "high income" **LPG consumers** are able to enjoy a lighting consumption that is 30 times as high, with one third of the monthly cost

19/ There is "a lack of concensus among the experts as to the interpretation of this demand curve for lighting and the conclusions derived from it of estimates of consumer surplus. The authors of the report view this curve as a lighting demand curve, while other experts consider it to be merely a plot of unit fuel costs against monthly household use of four fuels for lighting at different levels of consumption and expenditure and not a demand curve".

of fuel. Their lighting benefits from a switch to electricity are relatively modest: the welfare benefits have to do more with ease of use than with lighting quality.

5.27 As far as the satisfaction of basic lighting services is concerned, the first priority of rural energy policy should be to meet the lighting needs of the candle-using consumers; the next priority should be to improve the situation of the kerosene consumers; the third priority should be to provide the LPG consumers with access to electricity. This conclusion has implications for the way rural electrification projects are implemented and provides guidelines for the kind of assistance that can be provided to the rural population that lives in settlements that are too dispersed for electrification.

5.28 Table 5.2 lists the economic benefits from a switch of the Asunta Valley households to electrification by category of household. The results show that **the economic rate of return for rural electrification is highly dependent on what category of household will be connected to the grid**: if all three consumer categories have the same connection rate, the average benefit per connected household for the first 15 KWh of monthly consumption will be US$ 11.43 per month or about US$ 0.76/kWh; if none of the candle consumers are connected, the average benefit per connected household will drop by a third to US$ 7.79 or about US$ 0.52/kWh. This result is likely as the poorest households in a rural electrification area cannot pay the US$ 100 that are charged to cover the cost of connection and internal wiring.

Table 5.2: Economic Benefits of Rural Electrification

Economic Benefits of Asunta Valley Electrification, by Origin (US$/month/household)

	fuel exp. savings	consumer surplus	electr. cost	Total	% of el. househ.	Contr. to average
Candle cons.	4.40	13.18	2.35	19.93	30	5.97
Kerosene cn.	1.94	5.69	2.35	9.98	50	4.99
LPG consume.	-0.42	0.42	2.35	2.35	20	0.47
Average	2.21	6.87	2.35	11.43	100	11.43

Source: UNDP/ESMAP, Rural Electrification and Demand Assessment in Asunta Valley, November 1990.

5.29 Two policy conclusion can be drawn from this analysis. The first is that the rural population's ability to pay for electricity is underestimated by those who argue for the need of subsidies to rural electrification for rural electrification projects. The second is that the upfront connection fees for low income consumers should be sharply reduced through loan financing. The loan can be recuperated through higher monthly tariffs. If the connection is provided "free," the utility can recuperate the US$ 100 within five years through a monthly charge of US$ 2.12 that is added to the electricity bill (10 percent interest rate). This monthly payment is less than the monthly cost-savings on fuels for candle users and equals the monthly cost-savings of kerosene consumers. This shows access to electrification by poor households is blocked by lack of up front cash rather than by inability to pay.

Promoting the Use of Modern LPG and Kerosene Lamps in Low-income Households

5.30 For rural household energy policy, the most important result from Table 5.2 is that most of the potential benefits that candle and kerosene consumers obtain from electrification can be achieved by a switch to **LPG lamps** as well. The second-best solution, a switch to **pressurized kerosene lamps** (the lighting efficiency of these is much higher than for wick kerosene lamps and close to the efficiency of LPG lamps), would still entail a substantial welfare and economic benefit to a candle-using household. Therefore, **the immediate priority of rural energy policy is to assist the poorest rural population in switching to pressurized kerosene and LPG-lamps** as the primary source of lighting. The reduction in the monthly fuel costs by a switch to a LPG lamp provides such a huge rate of return to the consumer (see text box) that the continued use of candles and kerosene wick lamps can only be classified as a major market imperfection. The causal factor for this is the scarcity of cash for buying the needed auxiliary equipment (the lamp). This is an example of the general rural problem of low incomes and inappropriate financial systems to serve the need of the rural population (see Annex X). Therefore, subsidized loans are justified in this case as they help to overcome a market imperfection.

> Based on the field data from the Asunta Valley electrification study, a candle (kerosene) using household that invests US$ 40 in the acquisition of a LPG lamp, will obtain cash and welfare benefits during the 3.5 years lifetime of the lamp, that amount to a NPV of $ 804 (449). The NPV of the monthly fuel savings of $ 4.40 (2.35) is $ 170 (83), and the IRR of the investment from the savings benefits alone is 124% (68%); and 50% (55%) if he buys two. The NPV of the consumer surplus of increased lighting levels amounts to $ 551 (283), while the NPV of the value of LPG expenditure on lighting amounts to $ 83. The net improvement in the yearly cash situation of a candle using household is US$ 38 or $24 if he buys two. This is equivalent to 7% and 4.5% of the average household income of the poorest 20% of rural households.

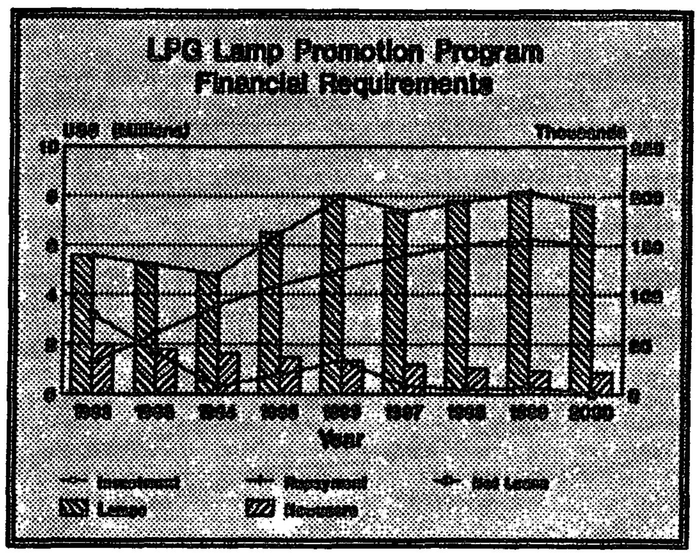
5.31 A reasonable policy target for the penetration of hydrocarbon-based lamps would be two lamps per rural household outside the electrified areas. At a low cost, such a program can provide substantial welfare benefits to the poorest part of the rural population. If the Asunta Valley figures on the relative use of the fuels for lighting are representative of rural Bolivia, the NPV of the value of the benefits of a program that provides modern LPG or kerosene lamps to the **120,000** (year 2000) households that use candles and the **200,000** households that use kerosene wick lamps amounts to US$ **182 million**. A pressurized kerosene lamp costs around US$ 20, an LPG lamp US$

40. 20/ The choice between promoting LPG or kerosene lamps will depend on which option can provide a given lighting quality at the lowest life cycle cost, and, next, on the relative availability of the two fuels. The investment needed to provide each household with two lamps would amount to US$ **12.8 million for a kerosene lamp program** and to US$ **25.6 million for a LPG lamp program.**

5.32 The financial cost to the Government of supporting such a program is difficult to estimate a priori. It involves costs for the administration of the program and financial losses on consumer loans that are not repaid. Nor is it possible to evaluate the size of the revolving fund that is needed to provide the loans to the consumers. The extreme case is illustrated in Figure 6.1 (see Annex XV) It assumes that: (i) the households that already have LPG lamps would ask for loans when they replace a worn out lamp; (ii) 50,000 target group households would benefit from the program the first year, after which the number of new target group households falls 10% every year until the year 2000, when the program ends; (iii) that every households purchases two lamps and replaces them after 3.5 years; and (iv) that the down payment is 20% and that the loan is repaid over 3.5 years.

5.33 In that case, the program would need a revolving fund of US$ 8.2 million (of which US$ 3.3 million would have to be paid in the first year) to provide loan finance to the customers through the local merchant stores. The cost for the administration and the monitoring of the program should be below US$ 300,000 per year. The annual demand for LPG lamps would be 140,000 lamps the first year (US$ 5.6 million investment if the price per LPG lamp is US$ 40) and stabilize at a level of 200,000 lamps per year (US$ 8 million). From 1990 to 2000, 1.5 million LPG lamps would be sold, at a total cost of US$ 61. The program should be merged with the program to increase the connection rate of low income households in rural electrification projects. The RDC should be responsible at the regional level for identification of the target group in the departments, the fixing of annual targets for results, the implementation and the monitoring of the program. The work can be subcontracted to NGOs, while the development of the market and the provision of finance should be done through the merchants that already sell LPG lamps.

Figure 5.1: Results and Costs of a LPG Promotion Program



20/ These figures are estimates and need to be confirmed by INE's rural energy survey.

Options for Pre-electrification

5.34 For the rural population that already uses LPG lamps, a LPG lamp promotion program is of no interest, unless it provides "free rider effects". Some households (e.g., large cattle farmers in the Beni) have a sufficiently high income, and correspondingly high electricity demand, to afford the installment of a small diesel or gasoline-powered generator. For the vast majority of the potential population these $ 1500-2000 generators are out of their financial reach. A less investment-intensive option is to cover the "lifeline consumption" of electricity through the installment of PV-systems or wind generators. In the Altiplano, a Spanish NGO is installing a PV system at a cost of US$ 750. Another NGO, SEMTA, that operates in the Altiplano has developed an equivalent system based on a 75W wind generator. The cost of this system is also around US$ 750. 21/ However, both systems are difficult to market for reasons on both the demand and the supply side.

5.35 First, compared to a consumer in a rural electrification project who pays US$ 100 for his connection, the upfront cost of a PV system is US$ 650 higher. Second, contrary to popular expectation, these systems do not have "cero" operating costs. In order to ensure continued operation, these systems need to be backed up by a monthly or bimonthly technical service, the cost of which, based on the experience in Bolivia, is at least 15 Bs. (US$ 3 per month). This operating cost equals the monthly expenditures on kerosene or on LPG for lighting, and is close to the cost of "life-line" consumption in rural electrification projects. Finally, the range of potential services is lower than in an electrification project -- to run a refrigerator on a PV system would require investments in additional modules. 22/ In addition, the risk of system failure is likely to be higher. 23/

5.36 The obstacle on the supply side is that a PV-promotion program is difficult to organize. Solar home systems are most appropriate in rural areas that will not be electrified by conventional means; but this very feature makes the provision of technical support and payment collection difficult. Effective collective options must be designed and implemented, and a viable

21/ The wind turbine system deserves continued testing. The advantage of the system is that the percentage of national components in this system is slightly higher. The disadvantage is that wind is a less available energy source than solar radiation in most of Bolivia, and that the potential for cost reduction is higher for PV modules than for the wind turbines. PV prices fell from a high of US$ 30-70 per peak watt in the early 1970s to about US$ 5 (retail) today. The price of wind turbines per rotor diameter fell by 30% over the same period.

22/ If we include the amortisation of the US$ 750, the monthly cost of the electricity will increase by US$ 10 - 16, if the system is amortised over 10 years or 5 years, respectively.

23/ By 1990 the household PV-installation project on Burias Islands in the Philippines had installed 110 small PV systems and one community battery charging system. Nearly half of the installations had component failures within the first two years of operation: 19 were battery failures, 22 lamp and ballast failures and 10 BCU failures. There were no reported module failures.

structure for providing technical support to remote areas must be identified 24/. The simplicity of solar home systems does not obviate the need for the careful design and production of reliable components. Although PV modules are technically and commercially mature, other balance-of-system components may not be, and should be, thoroughly tested before commercialization is initiated. Because poor component reliability can threaten successful commercialization, a national component policy should be defined before any program is launched. The Spanish NGO has made a laudable effort to reduce the cost of its PV systems by increasing local production of components. A larger-scale PV promotion program should start to evaluate the technical experience of the project.

5.37 PV-lanterns are an intermediate alternative between LPG/kerosene lamps and PV systems. The cost of the system is US$ 125 on the US market which means that they could probably be acquired at US$ 150 on the Bolivian market. There are good prospects for cost reduction in the next years as increased demand leads to economies of scale. The cost of a widely distributed system can be further reduced, if local grocery offers in-store battery-charging PV panels so consumers have to invest in the battery and the CFL only.

5.38 A Government-sponsored PV promotion program, therefore, should be targeted at two different market segments, and use different levels of subsidies:

(a) One market segment, to be developed by a 100% subsidy, is the homes of school teachers and other Government officials who: (i) work in rural areas outside the reach of grid-based systems and whose homes are not connected to a generator; and (ii) for isolated rural health posts where PV powered refrigeration of vaccine can be useful. However, as no study has been made on this market, therefore, the its extent is not known.

(b) The other market segment consists of non-electrified farming households. The Spanish NGO, referred to above, sells its PV system with an 80% subsidy to the consumer which is not a viable option for a larger program. PV systems and lanterns should be sold with a 10% down payment, a 40% subsidy, and a five-year payment arrangement for the remaining 50% of the cost. How large this potential market is depends on the number of households in the isolated areas which can afford to pay US$ 100 per year in loan repayments, with due account of the other needs of the household. This needs some investigation before a qualified guess can be made. But presumably, it is somewhere between 5 to 20% of the households, or 20,000 to 80,000 of the year 2000 rural households. This puts the annual cost to the

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24/ In the Burias Island project, it was decided that sending out a technician to collect payments from the consumers in remote areas would cost more than what would be collected. Therefore, the remote farmers were expected to pay when they came to town to buy provisions. This voluntary nature of repayment led to an arrears rate of 40%. A collection option could be to make groups of consumers responsible for payments of members; for example, members of the group who have not yet had a system installed will not receive one, until members of the group who already have them are current in their payments.

Government of such a program at US$ 0.75--3 million per year (excluding the cost of administrating such a program).

Measures to Reduce the Cost of Rural Electrification

5.39 In view of the high cost of rural electrification projects, attention has to be paid to ways of reducing the costs and maximizing the benefits from the investments. This involves promotion of sufficient investments in detailed feasibility work; promotion of the productive use of electricity; and the use of least-cost options for power production in isolated grids.

> The results of the UNDP/ESMAP financed feasibility study for the Agroyungas rural electrification project indicate that investments in proper pre-feasibility work pay off in terms of cost savings on plant investments: The investment in the prefeasibility study was less than US$ 100,000, the identified cost savings compared to the original estimates amounted to more than US$ 1 million. About 60% of the cost savings were caused by a lowering of the demand estimate, the remaining 40% resulted from a switch to a lower cost design. Thus, detailed field work to provide inputs for the demand analysis is as important in identifying least-cost investments as the work on the technical identification of least-cost designs.

5.40 The productive demand for electricity is usually lower than the household demand for electricity in rural electrification projects (see Annex VIII for an analysis of the productive demand for electricity in rural Bolivia). But it is an important determinant for the overall profitability of the project:

(a) From the point of view of a utility, productive end-uses not only have the effect of load-building, they also augment the off-peak load. The marginal cost of investment for satisfying a larger productive demand for electricity is relatively low. A high level of productive demand, therefore, decreases the cost of investment per kWh of demand or kWh of consumption.

(b) The economic and financial viability of rural electrification projects depends on a rapid growth of demand which is a function of economic activity. A potentially large productive demand for electricity is an indication of fast local economic growth, and thus faster growth of rural incomes and electricity consumption levels.

5.41 The existence of a productive demand for electricity is an important criteria for the selection of rural electrification projects by the regional development corporations and rural electricity cooperatives. Only areas that already have a basic infrastructure in place, such as access roads are considered eligible for electrification projects. In principle, DINE approves only publicly financed rural electrification projects where the productive demand makes up at least 50%. This passive policy of favoring productive uses of electricity can be supplemented by an active policy in favor of promoting productive uses for electricity in rural electrification projects. A promotion program should be directed both at new electrification projects and include a "backfill program" for existing rural electrification schemes. The implementation of the program ought to be monitored to permit evaluation of its costs and the benefits.

5.42 Dentro-thermal power plants of 3 to 4 MW are a potential but not realistic possibility for the generation of electricity in rural areas (see Annex XI). Feasibility studies were made for a US$ 10.3 million 3.5 MW plant in Trinidad and a US$ 1.4 million 1 MW plant in San Ignacio. But dentro-thermal plants should not be part of energy planning during the 1990s:

(a) The estimated cost of production of about US$ 0.16 per Kwh is not cheaper than the production cost of diesel-powered units.

(b) The establishment of reforestation schemes based on mono-cultures may not be environmentally sustainable in the Amazon areas.

(c) The technical and organizational risks are high. The plant requires extensive maintenance and cleaning, and extensive support must be given to the rural electrification cooperatives in planning, designing and implementing these generation plants.

5.43 Although only a fraction of the impressive physical hydropower potential has been developed so far, little development of mini-hydro power plants has taken place during the last 40 years. Some 65 mini-hydro plants with a total capacity of about 80 MW are in operation; half of these plants are used for mining, the other for "village" use.

5.44 The potential market for new mini-hydro schemes is small because of the absence of a local demand in the areas of high physical potential (see Annex XII). Most of the earliest rural electrification schemes were developed to serve the needs of a mine and were based on mini-hydropower. Mining development slowed down during the last decades because of natural resource and political factors; therefore, little demand for new mini-hydros came from this sector. Although the political situation for new mining development is more favorable in the 1990s, the resource limitations remain. Nor will there come much demand from village electrification schemes--the areas with the highest hydropower potential have a low population density. Fourteen of the national territory has mini-power potential. The optimal sites are located in 5% of the national territory. The area contains no more than 66 communities with populations ranging from 100 to 2,000. These communities permit the development of sites in the 20 kW to 100 kW range. In addition, some sites can be developed for isolated mini projects and saw mills. Finally, some agro-processing uses can be identified for direct-shaft mini-hydros, e.g., coffee. 25/

25/ The minihydro sites are too far away from the national grid to make it economic to develop these sites for production to the national grid.

5.45 From the point-of-view of the national energy balance, the potential contribution from mini-hydro development is small. But the feasible projects are economic and can be developed without need for subsidies at costs from US$ 1,000-1,500 per kW of capacity. The use of locally-manufactured components can be increased provided technical assistance is given to assist in the improvement of manufacturing capacity. For the next 10-15 years, there is a market for the development of 100 microplants and 10 miniplants with a total capacity of 3.5 MW. These projects will provide electricity to 40,000 persons, or 10,000 households.

C. Least-Cost Options to Cover the Productive Demand for Energy

5.46 Productive demand for energy in Bolivian agriculture is mainly a demand for water pumping and for the drying of agricultural products. The MEH and MACA should, therefore, concentrate activities around the least-cost satisfaction of these two needs. Provided that the technology can be manufactured locally, renewable energy systems will often be the most economic solution. Unfortunately, up to now the work on renewable energy systems in Bolivia has lacked focus.

5.47 The use of irrigation is expected to grow rapidly during the 1990s. Some expansion of irrigation will take place through gravity based systems, some through mechanical systems. In areas, where the latter is feasible and the wind potential is sufficiently favorable, wind water pumps can be an attractive option -- the life cycle cost per m^3 of water of a typical US$ 1,000 wind pump with a 5 meter rotor is lower than for small gasoline powered units. PV-water pumps are an other option, but presently, these systems do not yet represent cost-savings over diesel and gasoline-powered pumps.

5.48 Three different producers are producing wind mills for water pumping in Bolivia (see Annex XIII). The best wind potential is found in Santa Cruz where some 600 wind powered water mills have been installed so far. In some local areas of the Altiplano, the wind energy potential is also sufficient to enable the use of wind turbine for water pumping. It is impossible to estimate what the annual market would be for these systems, but presumably, some **100 - 400 small systems could be sold per year.** The MEH can support the development of the wind mills by financing a solid monitoring and testing of the marketed systems in Bolivia, and by supporting studies on the wind energy potential in areas where a larger expansion of irrigation is expected during the 1990s. The marketing of the systems has to be left to MACA.

5.49 In other parts of the world, rural water pumps have been developed that can be moved by animal traction. This may be a particular attractive option for water pumping in dispersed rural farms in Bolivia, as studies made by the ESMAP/MEH project indicate that there is idle capacity of animal power. Unfortunately, the study is totally supply-based. It provides information on the availability of animal power and on existing techniques for making use of animal power. No information is given on the demand for animal traction or on the economic benefits from the use of new technologies for animal traction. A verification of the market for novel techniques for making use of animal power in agriculture and in rural transport and the eventual implementation of dissemination programs should be undertaken by MACA.

5.50 The University of Cochabamba has developed low-cost solar dryers for the drying of fruit and vegetables that can be self-constructed by the farmers, provided that they acquire plastic films. The technology is low cost, fully matured and can be disseminated by MACA. Since this technology has a widespread, and not local specific application in Bolivian agriculture, a nationwide campaign for the dissemination can be implemented. It will yield insights on how new energy technologies can be marketed, and therefore have a value that goes beyond the benefit from the technology as such.

5.51 During the 1980s several programs in favor of the development of biogas energy were launched in Bolivia. By 1990, some 48 biogas digestors were installed half of which were out of operation. In part, the experience reflects the technical difficulties of biogas programs in other parts of the world, in part the difficulties were caused by a lack of focus on viable systems for appropriate regions. Instead, attempts were made to develop biogas digestors for all regions, including the Altiplano, for which they were totally inappropriate. Lately, a potentially promising concept was conceived, whereby PIL, the Bolivian dairy company was to loan finance the installation of 10 biogas digestors at small farms, with repayment being made in milk deliveries. It was not implemented as the GTZ, which during recent years financed biogas development in Bolivia, ended its involvement in 1991 due to disappointment with the results. Biogas development is an interesting concept. But in view of more pressing priorities and the its low chances of success, additional resources for its development are not justified in this decade.

VI. A STRATEGY FOR RURAL ENERGY PLANNING

A. The Definition of a Strategy

6.1 Because the welfare of a majority of the rural population is seriously affected by the existence of market imperfections to a rational use of energy in rural areas, the MEH must replace its passive role with an activist strategy that provides genuine leadership to guide the work of the RDCs and the NGOs and that more than doubles the level of energy investments per rural capita. The formulation of a strategy for rural energy policy involves four steps: (i) the definition of the key objectives for rural energy policy; (ii) the definition of the key programs to fulfil these objectives; (iii) the definition of the most appropriate institutional framework to promote the policy objectives; and (iv) the definition of what regional energy planning work has to be done.

B. Policy Objectives and Programs for Rural Energy Development for the Year 2000

6.2 Based on the analysis of the rural energy issues, the <u>immediate objectives</u> for rural energy policy during the 1990s should be (i) to improve the quality of lighting; (ii) to develop cost-effective micro- and mini-hydro projects; and (iii) to rationalize the use of energy for cooking. The <u>quantitative targets</u> for the corresponding three <u>programs</u> that should be attained by the year 2000 are:

<u>Program 1: Improving the Provision of Lighting Services</u>:

<u>Objective</u>: To provide all rural households with the means to enjoy a lighting standard that is equivalent to the "lifeline consumption" levels in electrified rural villages

<u>Quantitative Targets for Program Components</u>:

(a) In already electrified areas, the MEH should increase the connection rate of potential household customers to at least 90% by making loans available to low-income households for the financing of the connection costs.

(b) In non-electrified areas, the use of candles and of wick kerosene lamps as the principal means for lighting should be reduced to less than 10% of rural households by a vigorous promotion of LPG and of pressurized kerosene lamps.

(c) The level of a commercial demand for PV systems, wind power, and PV lamps should be tested in a pilot project where the subsidies are not higher than 40%. If the result is positive, the program should be extended to a national program supporting: (i) the establishment of commercial enterprises that disseminate PV-systems and lamps and provide service for their maintenance; and (ii) promote the development of a market for the systems by providing loans and subsidies to their acquisition.

Program 2: Development of Cost-Effective Micro and Mini-Hydro Projects

Objective: To maximize the rates of returns from rural electrification projects.

Quantitative Targets for Program Components:

(a) A program for the development of hydropower at some 100 micro-sites and 30 mini-sites over the next 15 years should be implemented. The program should include support to local industry for maximum local production of components. The value of this program should be enhanced by a number of supportive activities, including:

(b) A pilot project for the promotion of productive uses of electricity should be implemented for both already electrified areas and for new rural electrification projects. If the balance between the cost and the benefits turns out to be positive, a nationwide project should be implemented.

(c) Seminars on least-cost designs and the use of demand analysis as a tool to fine tune designs should be carried out for staff involved in the planning and implementation of rural electrification projects.

Program 3: Rational Use of Energy for Cooking

Objective: To protect the environment against energy consumption patterns that lead to ecological damage that threaten the long-run sustainability of local agricultural production.

Quantitative Targets for Program Components:

(a) A program for the promotion of improved kitchens and of pressure cookers should be tested and evaluated before the end of 1993 in a pilot area in the Altiplano. If viable, the program should be extended to cover 30% of biofuel-consuming households by the year 2000.

(b) Technical and loan assistance should be given to private entrepreneurs for the establishment of rural LPG bottling plants and LPG distribution services, so that 70% of rural consumers will fall under the direct zone of supply of these centers. In addition, the following supportive activities could be undertaken:

(c) A program for promoting the insulation of kilns in the gypsum, tile, brick and limestone industries should be tested in a pilot area, and if found viable, the program should be extended to cover all "commercial scale" enterprises in this sector.

(d) The possibility for developing a viable scheme for energy-relevant reforestation projects will be analyzed during 1992.

C. Providing an Efficient Institutional Framework for Rural Energy Planning

Principles for a Rational Institutional Framework

6.3 A series of institutional reforms are needed to implement the programs efficiently. (see Annex XIV). The institutional framework should: (i) allow to make maximum use of market forces, and (ii) to take into account (a) the respective strengths and weaknesses of the public sector and of the NGOs, and (b) the large socio-environmental diversity of rural Bolivia.

> A constraint for rural energy development is the inefficiency of the state agencies caused by low public sector salaries and the extreme politicization in Bolivia. With every shift in the balance of power, most personnel also shift, along with policy priorities. Since rural projects have to oriented for the long term, the sustainability of rural development programs is seriously affected. The low salaries affect staff morale and make it difficult to keep qualified staff. As long as this situation is unchanged, organizational improvements in individual institutions and changes in favor of a more rational structure of planning at the macro-level, will have little impact.

6.4 The MEH should formulate the general objectives and goals, but should leave it to the local implementing agencies to define how the goals can best be reached in individual areas. The MEH must have a well-designed system for monitoring and evaluation at its disposal to be able to control that the objectives are reached in the different areas and to provide guidance on best practices to the RDCs and the implementing agencies.

6.5 Thus, the reforms that are proposed below have three basic aims: (i) to strengthen the policy formulating and monitoring capacity of the MEH, (ii) to improve the coordination of activities between MEH and MACA, and (iii) to provide a framework for a more effective use of the RDCs and of the NGOs in project implementation and identification.

Division of Roles Between the MEH and MACA

6.6 At the policy formulation, planning and coordination level, the lack of coordination between the MEH and MACA needs to be corrected. MACA does not regard as its function to be involved in rural energy planning and implementation activities. Yet, rural energy issues and agricultural development patterns are interlinked. Rural **productive energy demand** is a derived demand from mostly agricultural and agro-industrial activities, and rural **household energy demand** has repercussions on agricultural productivity -- the consumption of biomass for energy purposes, e.g. dung, competes with its use as a fertilizer; and the exploitation of fuelwood resources for cooking may lead to soil erosion. Thus, although the MEH has the overall responsibility for the definition of policy targets for rural energy; some issues fall under the responsibility of the Ministry of Agriculture; and some need close coordination. It makes little sense to establish, for example, financing mechanisms for energy purposes outside the framework of the financing system in the affected area for small agricultural, or agro-industrial projects, in general. It would be equally suboptimal not to cooperate and coordinate collecting of survey information on rural families.

6.7 The division of responsibility for individual issues should be determined by institutional expertise. A rational cut-off criteria for the involvement of the MEH would be whether or not an activity affects the physical flows of the energy system. If an activity has a potential direct or indirect impact on the consumption of fuels, the energy sector is affected and it becomes an issue for energy policy. In addition, the MEH can support research in agricultural applications of relevant spin-offs from R&D activities related to the physical energy system, such as solar dryers of agricultural products. The dissemination of the systems should be left to MACA-affiliated institutions.

> Some classify greenhouses and the less expensive "carpas solares" as solar energy systems because they make use of solar energy. It is more appropriate to refer to these as agricultural techniques. The development and promotion of these techniques is an issue of interest for MACA and for the Ministry of Nutrition. The promotion of carpas solares in the Altiplano makes it possible to widen the range of food to the local population. Activities within animal traction refer to the development of new plows and carts that make more efficient use of the animal's traction power. The delivered power in kW of the natural strength of the oxen is increased. Since Bolivia has 200,000 oxen and only 5-7,000 tractors, these activities are potentially interesting. But again, the implementation of programs in this area demands an

6.8 Based on this decision criteria, as far as the MEH is concerned, rural energy policy deals with:

(a) All issues related to **household energy demand** (except reforestation)

(b) Within the area of **productive energy demand** issues dealing with (i) fuels, (ii) renewable energy systems that can replace fuel consumption, and (iii) renewable energy systems for productive applications making use of know-how that has been created from general energy R&D work, e.g., solar dryer systems.

6.9 Since energy experts cannot provide any specific expertise to activities related to "**animal traction**" or to the **promotion of greenhouses**, these subjects fall outside the responsibility of the MEH. Only MACA and its associated institutions can provide the needed sector expertise capable of making a proper evaluation of project proposals in this field. Reforestation activities are handled by the Forestry Department in MACA.

6.10 The "Consejo Directivo de Planificacion Energetica" provides a model for an efficient framework for coordinating of sector policies between the two ministries and between the executing agencies. The Consejo was created in 1989 to improve the coordination between the MEH and the sector enterprises, ENDE and YPFB. A similar "**Consejo Directivo de Planificacion Rural de Energia**" should be established with representatives from MACA, MEH, the CDRs and the NGOs. The to-be-created "**Direccion de Energia Rural**" in the MEH should function as the secretariat to the Consejo, which is led by the Subsecretario de Energia. The function of the "Consejo" would be to identify national priorities for interventions and investments and policies for two to three years at a time on a rolling basis. Twice a year, the Consejo would convene representatives from MACA and the MEH only to review common policy objectives and the evolution of projects. Both ministries should be represented at subsecretarial level. Once a year, the Committee should be enlarged with representatives from the RDCs and the NGOs, in order to promote a consensus on the main immediate targets for sector development and to make a critical review of the progress and the experiences of the sector work during the past year.

<u>The Vertical Division of Labor in Rural Energy Planning and Implementation</u>

6.11 Rationally, the vertical division of labor in the planning system must ensure that the implemented projects are based on national priorities and that the implementation is adapted to local needs. Within the rural energy planning framework, there are basically three functions to fulfill: (i) policy formulation, implementation and monitoring at the national level, (ii) project implementation and coordination at regional level, and (iii) project implementation at micro regional level. This suggests the following division of labor:

(a) At the strategic level, MEH, in consultation with MACA, would have four tasks: (i) formulating the objectives, the policies and the programs for sector work, (ii) identifying sources of finance for the execution of programs, (iii) preparing calls for tenders for the implementation of program components that are carried out at the national scale and selecting executing agents, (iv) and finally, monitoring and evaluating the results of the policies and programs.

(b) At the functional level, the CDRs would have four tasks: (i) regional implementation of the national energy programs, (ii) publishing the regional call for tenders for the selection of regional executing agencies, (iii) preparing the plans for the implementation of "collective" energy systems in their regions, such as rural electrification projects, and (iv) monitoring the performance of the executing agencies in their regions.

(c) At the operational level, relevant NGOs and universities would have two tasks: (i) executing the individual program components; and (ii) serving as consultants in technical advisory committees during the preparation of new program proposals. The executing agencies would selected on the basis of the quality of the proposals they have prepared in response to a call for tender.

Reorganization of the MEH

6.12 The implementing functions assigned to COFER would no longer be needed, while the policy formulation and result-monitoring skills of the MEH must be upgraded. To carry out the four MEH tasks defined above, COFER has been replaced by a "**Direccion de Fomento Energetica Rural**," which, unlike COFER, should be physically located within the MEH and staffed by a small and highly skilled team of three professionals and support staff. While all three professionals would work on the policy formulation side, two of the staff should work with the preparation of programs, and the third should be responsible for the organization of evaluation work and the establishment of data bases within and outside the Ministry.

6.13 The analytical quality of the staff needs to be high because it is more difficult for MEH to devise coherent programs for individual energy systems needed in the rural sector, than for collective energy systems, such as electrification grids and natural gas pipelines that are supported by professional feasibility studies made by ENDE, the YPFB and international institutions. Also, since the large welfare impact of rural energy work is not reflected by its modest impact on the national energy balance, the staff must be able to support its proposals with strong arguments to boost the priority of rural issues within MEH. Finally, the staff needs to be sufficiently influential to be able to counter proposals from NGOs and CRDs that are geared to serve their own business interests rather than the interests of the target groups.

6.14 The Direccion can be small because: (i) the implementation of the rural energy programs would be based on the principle of "subsidarity", i.e., only tasks that local agencies cannot handle will be resolved by the RDCs, and only tasks that cannot be resolved meaningfully at regional level will be handled at the national level by MACA and the MEH; and (ii) the Direccion will make extensive use of outside consultants. The Direccion, therefore, has to be provided with a sufficient budget for this purpose.

6.15 The outside consultants can be provided by NGOs, university institutes or private consulting firms in Bolivia. The selection of consultants for major tasks should take place on the basis of a call for tender, i.e., published by the Direccion, while consultants for minor tasks should be drawn from a list of consultants/firms that have responded to a yearly or biannual "expression of interest".

6.16 Unfortunately, the new DEFER already suffers from the same defects as COFER, including, a lack of funds, and low salaries. DEFER, thus, cannot as yet function effectively, a situation that will persist for some time to come. Given the need to provide effective leadership and guidance to promote economic development in rural areas by providing least-cost energy to productive needs of agriculture, rural industries and households, it is recommended to create a semi-autonomous, and technically well-staffed, Advisory Unit inside MEH (similar to the unit that developed the National Energy Plan) that will be financed by a bilateral donor. This Advisory Unit will train DEFER staff and prepare them for their pro-active function in promoting rural development through the focussing on technologies that have genuine market prospects. Also, to prepare project proposals for the investment and supportive activities identified in this report for submission to donors, to assist in operationalization of the funded projects as well as of the institutional arrangements recommended in this report. Finally, to assist the 'Consejo' in developing ways to achieve the objectives of the rural energy strategy formulated by the Government. This Advisory Unit could function for 3-5 years, after which its functions could be taken over by DEFER. Because by that time proven procedures and methodologies will have been tested in practice, while skills and abilities will have been honed through 'learning by doing' this transfer of tasks to DEFER should pose no problems. The Government, however, needs to allocate sufficient funds to enable DEFER and the 'Consejo' to continue to perform its functions effectively.

D. Methodology for the Preparation and Implementation of Rural Energy Projects

Preparation and Implementation of Rural Energy Programs

6.17 Ideas for initiatives could come from the political system (the Minister of Energy, Cabinet, Parliament, etc.), from the Direccion itself, or from the annual meetings of the "Consejo Nacional de Planificacion de Energia Rural." Viable project ideas will be prepared into programs by the Direccion with, if needed, the help of outside consultants and be presented to the political level for approval. Once approved, funding can be sought for the program either from the national budget or from donors. If donors are interested, they will usually be able to find the financial means. Apart from rural electrification projects, rural energy programs usually demand rather small budgets, as they are not capital-intensive.

6.18 While attempts are made to identify sources of funding, the work on the preparation of the programs can continue with the finishing of details, the preparation of a plan for evaluation of the programs and the drafting of calls for tender for the implementation of program components. The evaluation plan will contain prescriptions for the internal and the external evaluation of the programs effectiveness and the contractor's performance. Depending on the characteristics of the program, its implementation can be contracted to either: (i) one main contractor for overall programming and quality control at the national level and to other contractors at the regional level (call for tenders to be published by the RDCs), e.g., the LPG lamp program, or (ii) to one contractor only, e.g., the responsibility for maintaining a data base on rural energy issues. Separate calls for tenders are issued for the work of external evaluators that carry out mid-term and ex-post evaluations of individual programs. The selection of contractors/executing agencies that bid on the execution of a program or evaluation job should be based on both the price and on the quality of the proposal. A basic principle should be that different consultants are hired to carry out the appraisal, the implementation, and the evaluation of programs. As the evaluation of programs needs to be undertaken by experts, MEH should limit evaluation contracts to institutes from two or three universities only.

Preparation of Micro-Regional and Macro-Regional Rural Energy Plans

6.19 A common mistake in rural energy planning in other countries has been to prepare rural energy plans on the basis of rather large investments in detailed data collection on the situation in the different rural areas, but without defining a priori what the data should be used for. Data on the availability of local energy resources and on local energy demand would lead to identifying what the key issues to be solved. In practice, this approach usually leads to the accumulation of a huge amount of quantitative data, but little qualitative data on what the real issues and options are. These "regional energy plans" then accumulate dust on a shelf without being put to practical use.

6.20 The reason for the failure of this approach is that a rural energy plan can only be meaningfully prepared on the basis of well-defined policy objectives and a knowledge of what kind of investments are available for its implementation. This kind of mistake is not made in rural electrification as the planners in a rural electrification cooperative or in a RDC precisely know what kind of data they need and what the financial constraints are for project implementation.

6.21 Preparing micro-regional plans for implementating the proposed strategy will be objective-oriented and resembles, therefore, the rural electrification planning approach. As the strategy dictates what kind of projects are to be implemented in the next three to five years, the data collection work at micro-regional level can be tailored to what is needed in order to design the projects at local level, to set local quantitative targets and to monitor the results. To this end, data collection will be undertaken through "rapid rural surveys" and "beneficiary assessment" techniques. The collected information should be stored in regional data bases so that the RDCs or implementing agencies can draw on the data for other purposes.

E. Implementation of the Strategy--The Next Step

6.22 In order to implement the proposed rural energy strategy, MEH needs to receive technical assistance for the buildup of the "Direccion de Energia Rural". The assistance should include the provision of an institutional energy expert over a two-year period and short-term consultants in the fields of LPG distribution, data bases, rural credits, rapid survey techniques and evaluation work. The tasks are to draw up the terms of reference for the staff of the Direccion, to assist in the preparation of the programs, the establishment of data bases, the drafting of call for tenders, and the preparation of evaluation programs. MEH should initiate discussions with donors to obtain agreement in principle to finance individual programs of the strategy during the 1990s.

Annex I: Consultant Reports Prepared for the Strategy

Biomass Technology Group and Oscar Aguilar	"Stoves, Kilns (and Dendro-Thermal Plants) for Rural Bolivia, October 1990.
Ing. Oscar Von Borries	Reforestacion en el Altiplano, Valles y Otras Areas de los Llanos, Afectadas por la Deforestacion en la Produccion de Leña y Carbon", October 1990.
Federico M. Butera, Jesús Durán B., Cesar Sevilla	Institutional Analysis of COFER, September 1990.
Renata Claros	Impacto Social de la Utilizacion de Energia en la Mujer de Areas Rurales de Bolivia, June 1990.
COWIconsult	Evaluation of Wind Energy in Bolivia, February 1990.
Edwin Delgado	Viabilidad de la Energia Eolica en Bolivia, August 1990.
Jesus Duran B.	Estrategia de Energia Domestica y Rural de Bolivia, December 1990.
Frede Hvelplund, Cecar Sevilla, Gonzalo Guzman	Rural Energy Planning and Implementation in Bolivia, October 1990.
Myk Manon, Ronald Orozco, Orville Voxland	Issues in Rural Electrification Organization, Planning and Productive Uses in Bolivia, April 1990.
William G. Matthews, Jorge Calderon	LPG Distribution - Bolivia Household and Rural Energy Project, March 1990.
Calvin J. Miller	Evaluacion del Credito Rural en Bolivia, June 1990.
Claudia Ranaboldo	Bolivia Household and Rural Energy Project - Promotion of Improved Fuelwood - and LPG Stoves, May 1990.

Claudia Ranaboldo	Promocion de Fogones Mejorados en Areas Rurales de Bolivia, October 1990.
A. Tarnawiecki	Bolivia - Review of Alcohol Fuel Substitution Proposals, June 1990 (rev. September 1990).
René Terán, Martin Villarroel	Informe de la Consultoria Sobre Energia Solar, Biogas y Traccion Animal, October 1990.
Orville Voxland	The Status of Mini Hydro in Bolivia, September 1990.

Annex II: Tables on Urban Household Energy Consumption

Table II.1: Household Income and Expenditure (Bs./month)

	Expenditure			Income		
	Mean	Lowest quintile	Highest 1%	Max	Lowest	Highest
La Paz	824	508	4058	716	197	9530
Oruro	510	355	1570	461	152	3532
Quillaco	646	444	912	580	242	1810
Tarija	764	508	1400	571	217	2173
Trinidad	904	725	3566	896	288	7019
Total Urban	758			670		

Source: 1989 ESMAP/INE Household Energy Survey
1US$ = 2.55 bolivianos

Table II.2: Penetration of Fuel Use in Urban Households, percentage

	Total Urban	La Paz	Trinidad
Fuelwood	10	2	19
Charcoal	0.1	0	0.3
Kerosene	11	18	12
LPG	87	84	79
Electricity	93	98	85
Other Fuel	7	1	12

Source: 1989 ESMAP/INE Household Energy Survey

Table II.3: Total Urban Household Energy Consumption, by Fuel

	TOE/Year	% of Total
Kerosene	18,000	5
LPG	190,000	51
Electricity	158,000	36
Other	30,000	8
Total	396,000	100

Source: 1989 ESMAP/INE Household Energy Survey

Table II.4: Household Energy Expenditure by Income Class La Paz Households, (Bs./Month) 1989

Income Class	Kerosene	LPG	Electric-ity	Total	% of total income	% of total expenditure
Low	5	13	11	29	15.0	5.7
Mid-Low	3	13	14	31	9.9	5.3
Middle	3	13	18	34	7.3	5.0
Mid-High	1	14	25	40	5.9	4.6
High	1	13	36	50	3.0	3.8
V. High	0	13	68	81	0.8	1.8
TOTAL LA PAZ	14	78	171	37	5.2	4.5
TOTAL URBAN BOLIVIA				42	6.6	5.5

Source: 1989 ESMAP/INE Household Energy Survey

Annex III: Options for Rural LPG Supply

1. The supply of LPG to the rural demand centers is relatively efficient. 10 kg cylinders are transported from the urban LPG bottling plants by truck to the rural agglomerations. Consumers purchase their supplies either directly from the trucks or at the local merchant stores which sell LPG with a modest mark-up. As expected, studies by ESMAP revealed a correlation between the price of LPG and the distance of the rural demand center from the nearest bottling plant as well as the quality of the road. While a 10 kg cylinder cost 7 Bs. in La Paz, the highest encountered rural price (at a distance of 220 kms from the nearest bottling plant) was 11.5 Bs.: in the majority of the cases (for distances in the 50 to 90 kms range) the price was 9 Bs.

2. While the price difference can be justified with reference to cost within the present system of supply, the question is whether a more rational system can be established with lower costs and higher consumer convenience. While Bolivia has a very decentralized bottling system from the urban consumers' point of view, the bottling system is very centralized from the rural consumers point of view. This saves on investment cost in bottling plants, but involves costs resulting from: (i) an expensive transport of the tare weight of the bottle in addition to the liquid LPG payload; and (ii) an excessively large cylinder stock requirement for the total number of customers. 26/

3. An alternative would be to supply LPG in bulk to a series of rural networks consisting of small, simple storage and bottling stations that each serve a specific rural population center. Within Bolivia, a total of 32 potential networks have been identified where such networks can be built up. 27/ A typical network would comprise the following elements:

(a) A central office and garage/parking area. A location near the main bulk depot would be logical. Indicative level of investment: US$ 52,000. Central administration costs per year: US$ 22,000.

(b) One or more LPG bulk tank trucks, typically with a 4.5 tonnes payload. Indicative level of investment: US$ 40,000. Tank truck operating costs per year: US$ 15,000.

(c) Small storage depots, one for each targeted community, complete with a tank of 5 tonnes capacity to receive and store bulk supplies from the truck, pumps, hoses, and weigh scales for cylinder filling. The initial filling demand for each depot should be

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26/ This results from the immobilization of cylinders in transport and from the lack of supply reliability, particularly farther out in the distribution chain that leads to a hoarding of cylinders and a higher-than-normal product inventory in the system.

27/ For details see the MEH/ESMAP report, "LPG Distribution Bolivia" by William G. Matthews and Jorge Calderon. The designation of the 32 potential zones was based on the following criteria: (i) location of YPFB primary or secondary storage depots as supply sources; (ii) network of access roads; (iii) concentrated population within a radius of approximately 200 kms maximum of the depot/supply source; and (iv) the present state of rural LPG distribution in the particular area.

higher than fifteen 10-kgs cylinders per day. Indicative investment per mini-plant: US$ 48,000. Operating/Management cost per year and per mini-plant: US$ 5,000.

4. The economics of this system were calculated for a proposed demonstration project in the Altiplano involving two supply areas, comprising a total of 13 mini-plants. The proposal assumes that: (i) the initial sales volume would be 6.7 tons per day, (ii) the initial investment would cost $ 700,000, (iii) the first year operating costs would be $ 137,000, and (iv) the number of cylinders per client would be reduced from 2.5 cylinders in the present centralized distribution system to 1.25 cylinders in the "network case." The results show that the cost of bottling and transport/distribution to clients in each of the 13 population centers would be reduced from 4.87 Bs. ($1.6) per 10 kg. cylinder under the present system 28/ to Bs. 2.83 ($0.90) in the "network case."

5. While in theory, the "network system" offers some advantages, the implementation presents some difficulties:

(a) All consumers in an individual network ought to be confronted with the same standard price. Some regulatory body and/or transport fund would have to be established to ensure that the highest cost outlets in the networks are being supplied in the right proportion.

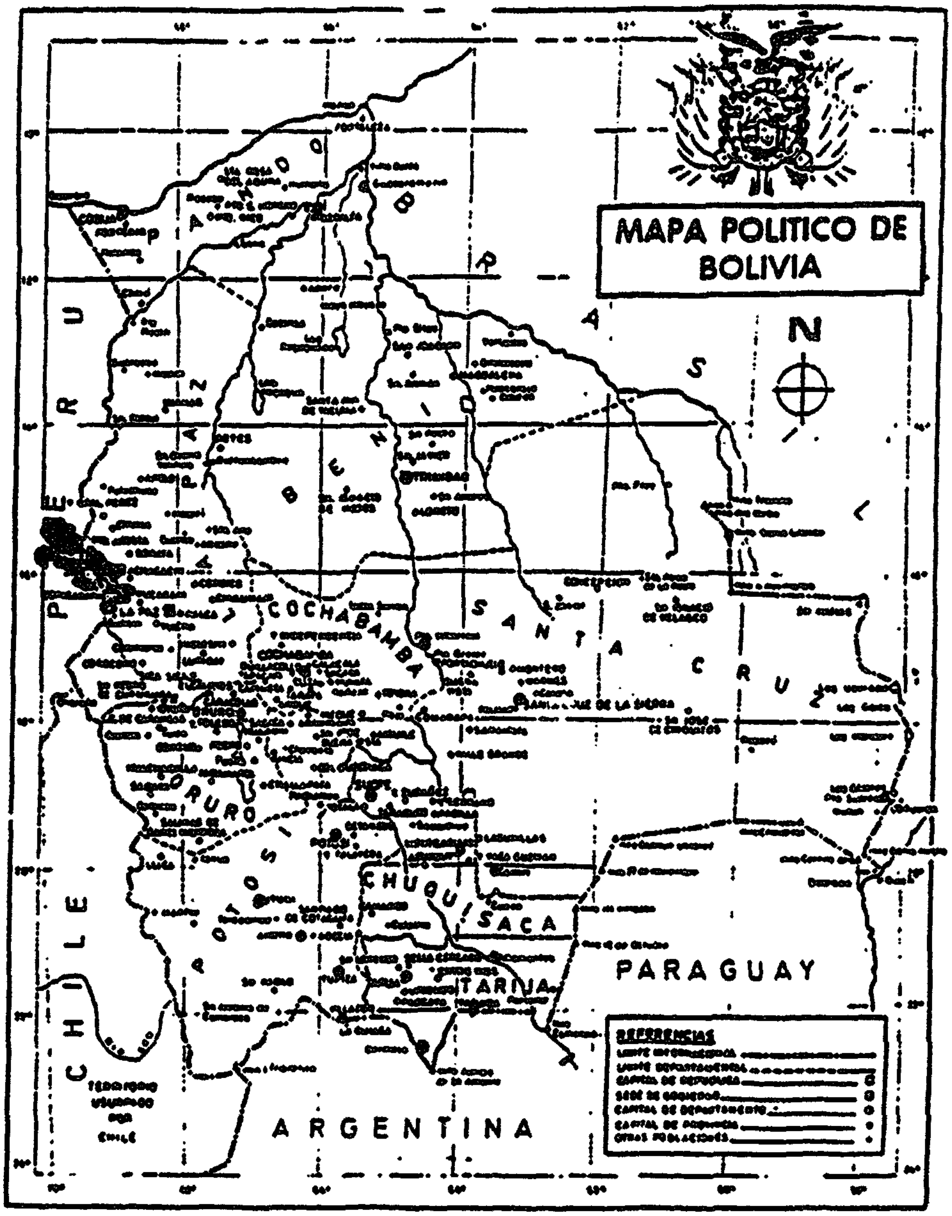
(b) A solution has to be found for cylinder servicing.

(c) Insurance and liability of the distributor vis-a-vis accidents by the customer has to be assured.

(iv) The issue of control and certification of product quality must be addressed.

28/ In 1990, the cost of LPG in the project area bought from the delivery truck was 8.5 to 9 Bs. per cylinder. The supply cost bulk ex YPFB La Paz is estimated at 5.5 Bs. per 10 kg. bottle in the prefeasibility study. This gives a 3 to 3.5 Bs. cost for the existing cylinder based distribution and bottling plant, or a cost that is similar to the forecasted cost in the demonstration project. Implicitly, the report therefore assumes that the present cost structure is unrealistic in the longer run.

Figure III.1



LOCATION OF YPFB
LPG DEPOTS/BOTTLING PLANTS

Figure III.2

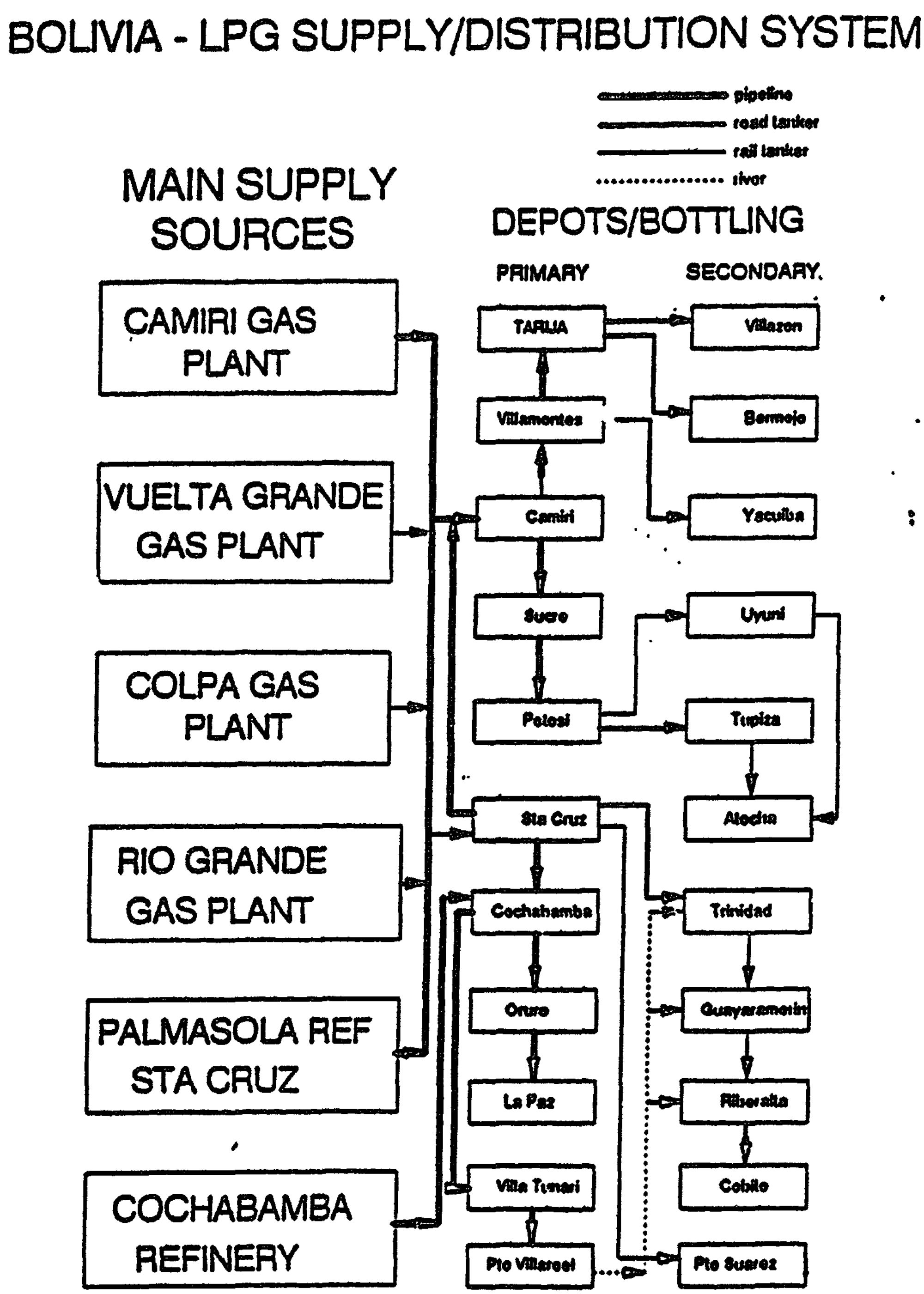
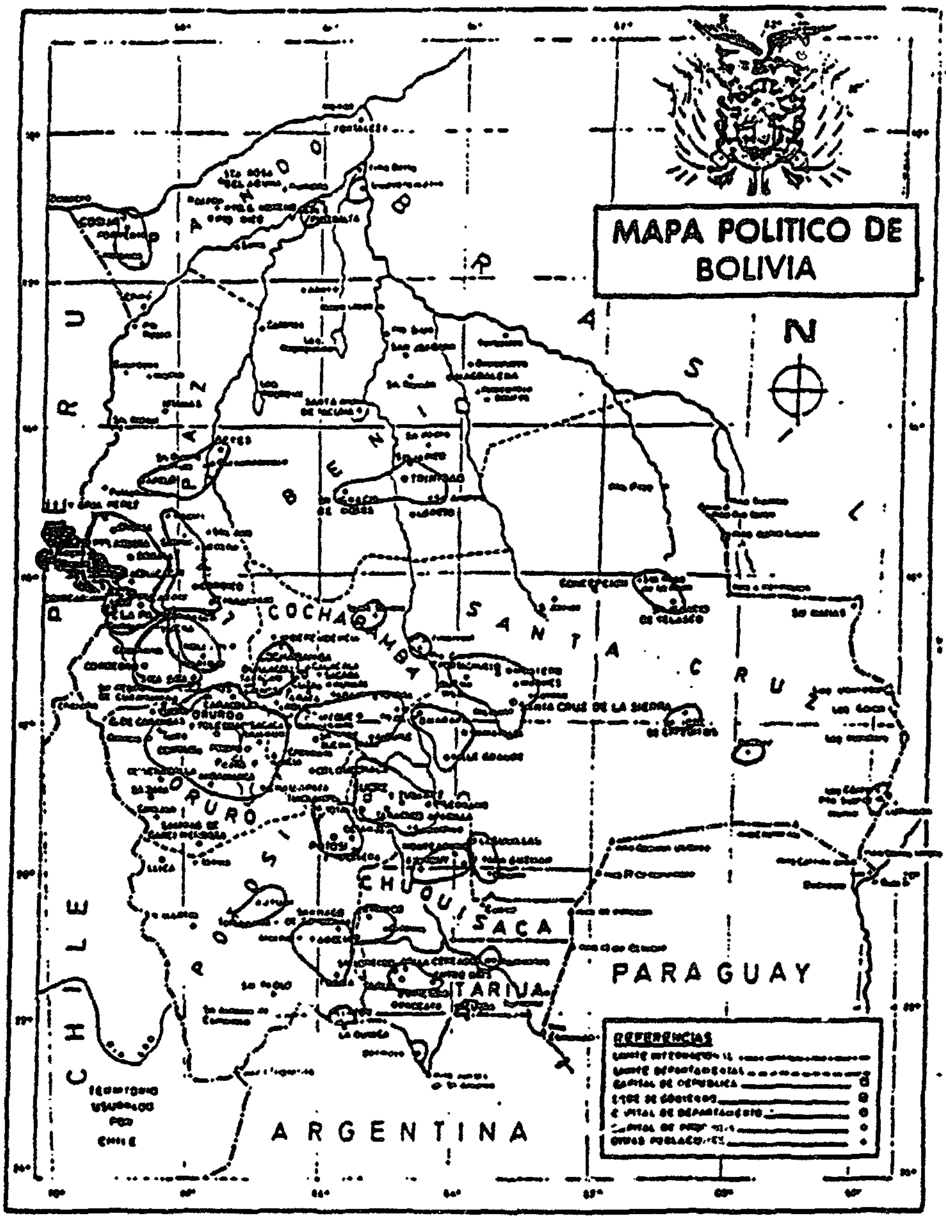

BOLIVIA - LPG SUPPLY/DISTRIBUTION SYSTEM
pipeline
road tanker
rail tanker
river
MAIN SUPPLY SOURCES
DEPOTS/BOTTLING
PRIMARY
SECONDARY
CAMIRI GAS PLANT
VUELTA GRANDE GAS PLANT
COLPA GAS PLANT
RIO GRANDE GAS PLANT
PALMASOLA REF STA CRUZ
COCHABAMBA REFINERY
TARIJA
Villamontes
Camiri
Sucre
Potosi
Sta Cruz
Cochabamba
Oruro
La Paz
Villa Tunari
Pto Villarroel
Villazon
Bermejo
Yacuiba
Uyuni
Tupiza
Atocha
Trinidad
Guayaramerin
Riberalta
Cobija
Pto Suarez

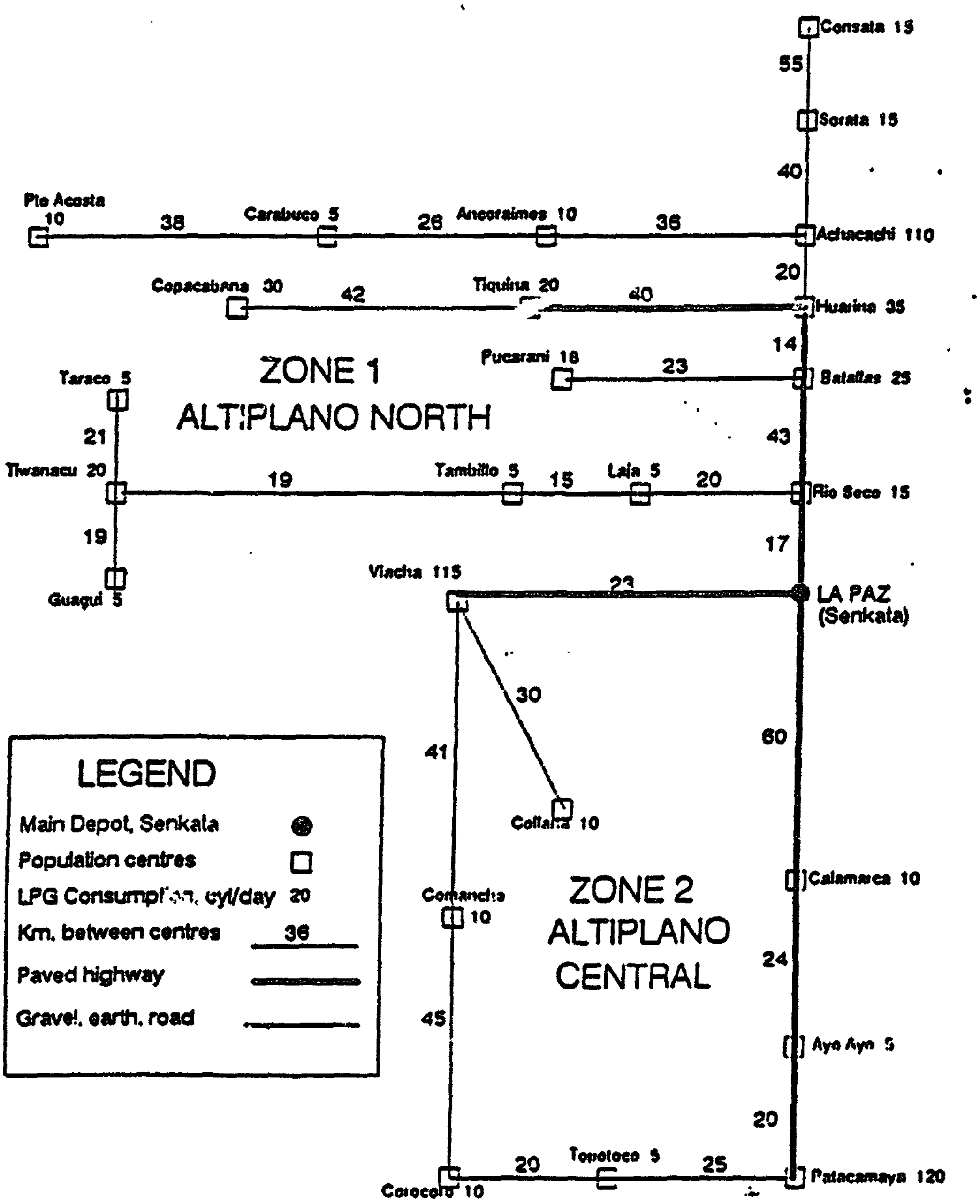
Figure III.3



TWO LPG MARKETING ZONES
SELECTED FOR DEMONSTRATION PROJECT

Figure III.4

LPG CONSUMPTION BY POPULATION CENTRE, ZONES 1&2
ALTIPLANO NORTH & CENTRAL, ESTIMATED FOR 1988



Annex IV: Energy in the Sugar Industry

1. The main sugar cane areas are located in the Department of Santa Cruz and Tarija where in 1990 sugar cane acreage has been estimated at 48,000 ha. and 11,000 ha., respectively. Sugar cane growing is labor-intensive and is carried out mostly in small and medium-sized properties. In 1987, less than half of the acreage was in land holdings of more than 90 ha.

2. The two main products derived from sugar cane are sugar and alcohol. The two main by-products are molasses and bagasse. Molasses is the syrup containing uncrystallized sugars separated from the crystallized sugar. Bagasse is the fibrous residue which remains after sugar cane is crushed and its juice extracted. In Bolivia, sugar is produced in five operating mills, four of which are located in Santa Cruz.

3. The level of sugar production has fluctuated widely during the last 20 years, reaching a high of 270,000 tons in 1979, and a low of 162,000 tons in 1988. Fiber content amounts to about 16% of the weight of sugar cane. Actual 1989 national production of wet bagasse (with 50% water) was estimated at 630,000 tons or approximately 340 kg per ton of crushed sugar crane.

4. The energy consumption in the plants can be substantially reduced. Plant design and production processes do not maximize efficient use of energy. Under appropriate technical conditions, bagasse can be used as a fuel to provide all the power needs of a mill (except for plant start-up at the beginning of the season). In Bolivia, bagasse is used in the sugar mill boilers, but not to generate power or supply the steam needed in the production of sugar. Some bagasse is dumped in surrounding areas or is burnt to avoid creating mountains of refuse near the mills. Other fuels -- natural gas, fuel oil and firewood and outside power -- are bought to operate the mills.

5. Production of molasses in 1989 was about 81,000 tons (44 kg per ton of sugar are crushed). All the sugar mills have distilleries attached to them to produce hydrated alcohol. In addition, there is one autonomous distillery. Total daily production capacity is 240,000 liters per day; average capacity utilization in the second half of the 1980s was 36%. Alcohol yields have ranged between 260 and 300 liters per ton of molasses. About 21 million liters of alcohol are produced each year, of which some 0.5 million liters are exported. Alcohol consumption for industrial and other uses is estimated at about 3 million liters; alcohol demand for beverages accounts for approximately 18 million liters.

6. The low rate of capacity utilization has encouraged efforts to use alcohol as a fuel. To obtain anhydrous alcohol, hydrated alcohol must be submitted to an additional process which generally consists of further distillation in the presence of a third component such as benzene. The anhydrous alcohol can then be mixed with gasoline, and the blend, containing up to 22% alcohol (gasohol), can be used in ordinary automotive engines with minor adjustments -- plastics used in gaskets and tubing are damaged when in contact with alcohol. Several feasibility reports have been prepared. A small (20,000 liters per day) blending plant for alcohol and gasoline has been built by

Etabol, a private firm owned by local investors at a capital cost of US$ 80,000. The firm operates a modern service station in the city of Santa Cruz, where the product is sold to customers at Bs. 0.07 below the price of premium gasoline of similar octane rating.

7. The results of the ESMAP/MEH project show that expansion of alcohol production in existing installations for use as automotive fuel could be financially attractive for the sugar mills engaged in the industry. The possibility of extending gasohol use to cover most of the country's consuming areas is not attractive. It would require additional installations at a cost of US$ 9.4 million. Neither the economic nor the financial results justify the execution of this project.

Annex V: Energy Demand in Rural Industries

1. Rural industries belong to the informal sector which implies that no statistics are available on their number, capacity and energy use. Field studies done by the project on individual rural enterprises produced data on annual turnover and energy consumption which is summarized in Table V.1. Investments to improve on the energy consumption should be in proportion to the size of the industry and to the role which energy plays in it. From the table it can be concluded that expenditures on energy are important in all industries shown, except for the small chicha breweries where energy costs are only 8 - 12% of the turnover. Since no information is available on the relative numbers of establishments, no conclusion can be drawn as to the overall importance of the energy consumption in the individual industries.

Table VI: Energy Consumption in Rural Industries

	Fuel	Quantity per year	SEC (MJ/tonne)	Turn-Over (Bs/year)	Energy (%-of-T.O.)
Limestone:					
Sucre	Gas	32	4.6	122,000	47
Collana	Dung	79	19	14,000	38
Sucre	Wood/Oil	33/12	12	5,000	34
Gypsum:					
Pando	Dung/Wood	135/83	5.5	31,000	45
Comanche	Dung	120	3.8	24,000	31
Brick Kilns:					
Viacha	Sawdust/oil	1430	3.8	122,000	54
Sucre	Wood	90	4.5	3,000	49
Chicha:					
Padilla	Woo^d^	1.4	19	9,400	8
Padilla	Wood	2.0	24	1,400	12
Padilla	Wood	9.1	34	1,400	8

The Limestone Industry

2. The limestone industry uses gas, fuelwood, or dung. All kilns are of the traditional design, made of mud bricks or stone. The data presented suggest that the substitution of biomass fuels by (used) oil and natural gas has a large downward effect on specific energy consumption, but that the fuel cost increases. Also the initial investments in oil or gas-using burners is higher than for biomass stoves. Therefore it seems that operational ease and local availability of fuels are more important determinants for fuel choice than price. The industry switches to gas when the trunk line is in the direct vicinity. Far from the trunk line, the energy supply is, or soon will be, a major constraint. In the Collana area, dung is collected from over a distance of more than 60 km.

3. Fuel consumption can be reduced by about 30% by insulation of the kilns. This would result in an 11% reduction of the total production costs. The cost of amortizing a loan to cover the cost of the investment is much lower. Therefore, a program to insulate the kilns is feasible because the savings are sufficiently large to interest the individual entrepreneurs, and the relative few number of establishments makes it easy to reach the target group.

The Gypsum Industry

4. Compared to limestone, the production of gypsum is about four times less energy-intensive, yet the fuel costs add up to approximately 30-45% of the turnover. This is explained by the use of expensive gasoline for milling. There is some scope for a program which would aim at insulating the gypsum kilns. Energy savings of 18% and cash savings of 5% of the turnover are feasible.

Brick and Tile Industry

5. As in the lime industry, all brick and tile industries in the vicinity of the natural gas trunk line have switched to gas. Large-scale brick and tile production with wood only occurs in the rural areas around Cochabamba. This industry has recently switched back to wood from LPG due to costs. In other semi-urban or semi-rural areas, the brick and tile industry using biomass fuels is a relatively small-scale operation -- the kilns are fired only four to five times a year. The rural industries producing for the rural market are even smaller and fire a kiln only once or twice a year. Activities to improve the brick/tile kilns which use biomass fuels should, therefore, focus on the Cochabamba area. Investments in other areas will not prove to be cost-effective.

Chicha Preparation

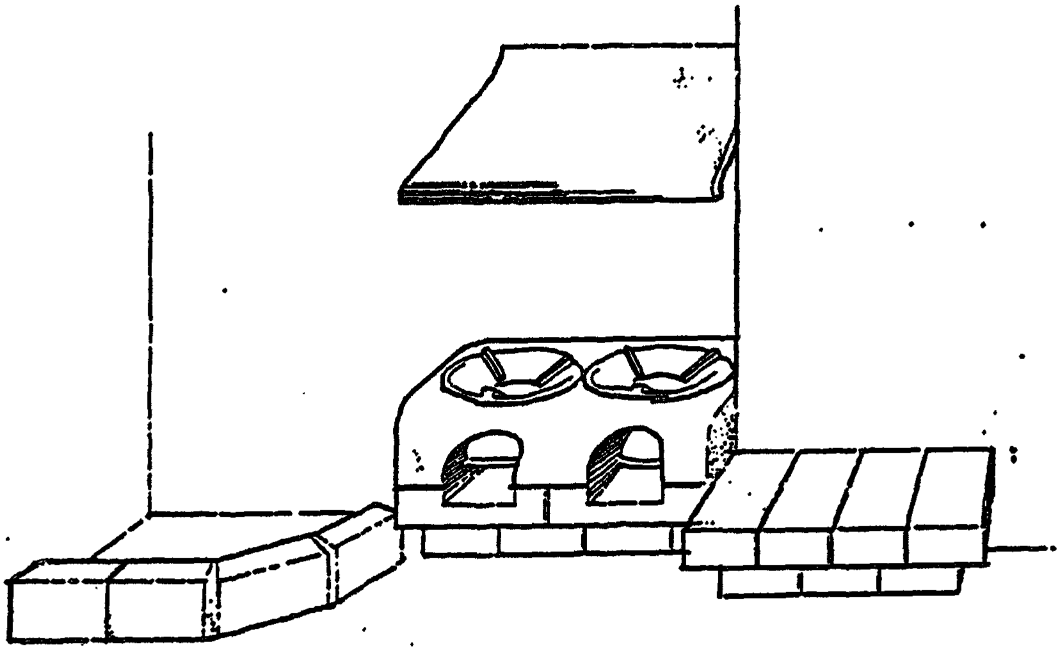
6. The data shows that the specific energy consumption varies between 19 and 34 MJ per liter. This variation is due to differences in the cooking time (making the chicha last longer) and to the fact that industrial alcohol is often added. The practice of adding alcohol is dangerous and should be strongly discouraged. The scope for improvements in chicha breweries is small. Energy cost is a small fraction of turnover, and the producers will, therefore, not be very motivated to invest in improved stoves. Some savings can be gained, however, by promoting improved cooking habits, e.g., using lids, reducing the fire once the boiling point is reached.

Charcoal Industry

7. Ninety percent of the charcoal produced in Bolivia is used in the ENAF smelting plant in Oruro. Production takes place in the Chaco from where it is shipped by train via Argentina to Oruro. ENAF accepts only charcoal with a fixed carbon content of 50% or higher. The price paid by ENAF increases with the fixed carbon content (US$ 120 for a fixed charcoal content of 70% or higher). Due to the quality control by ENAF, producers have invested in high-yielding charcoal yields. Most are half-orange kilns with a content of about 50 m^3. In the case of half orange kilns,

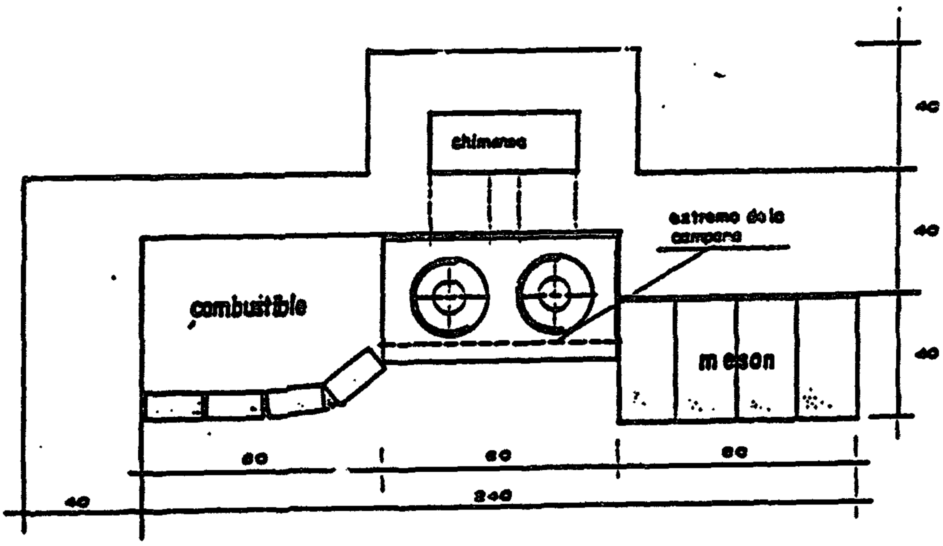
energy efficiency and charcoal quality go hand in hand. The efficiency of these kilns is approximately 26% on a wet weight basis. No energy-saving program is likely to have any impact under these circumstances.

Annex VI: Experience with the Dissemination of Improved Household Stoves in Bolivia

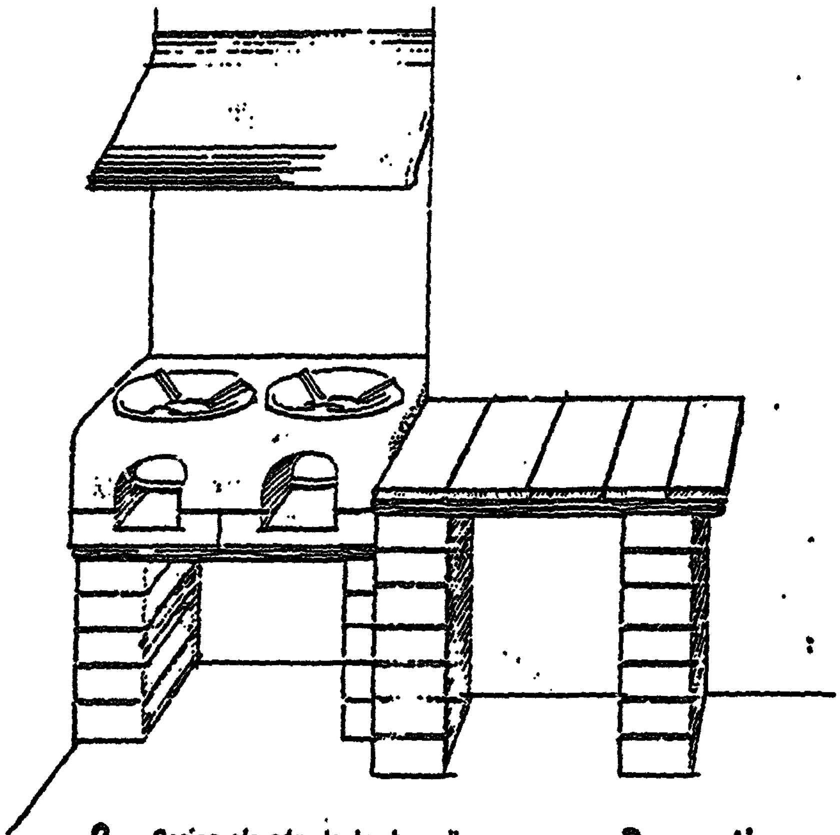


Perspectiva

1 Cocina baja de dos..hornallas con meson de adobe.

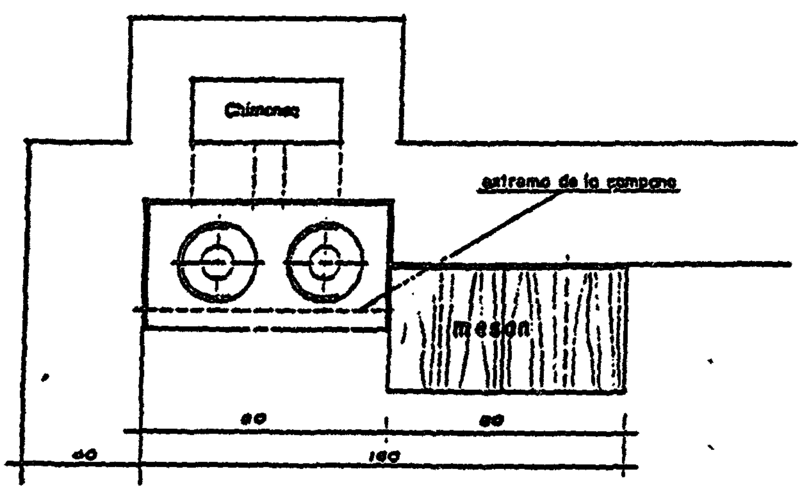


Planta Esc 1:20



2 Cocina elevada de dos hornallas con meson de trabajo.

Perspectiva



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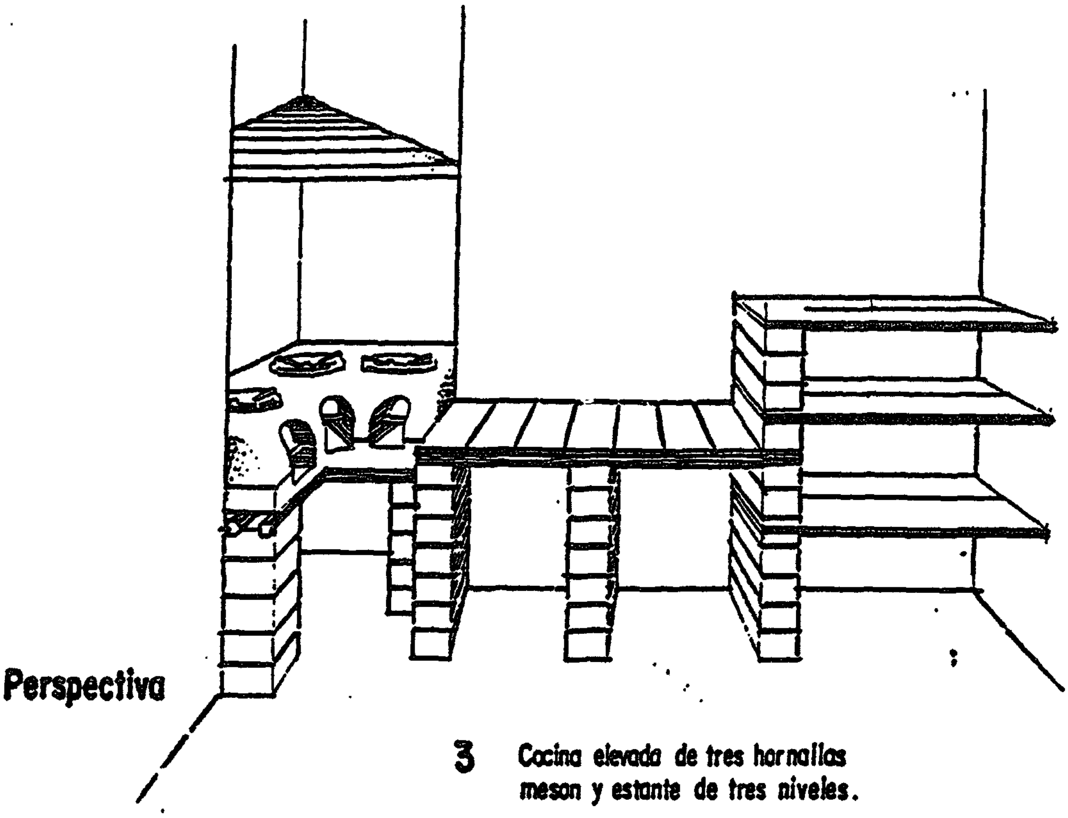
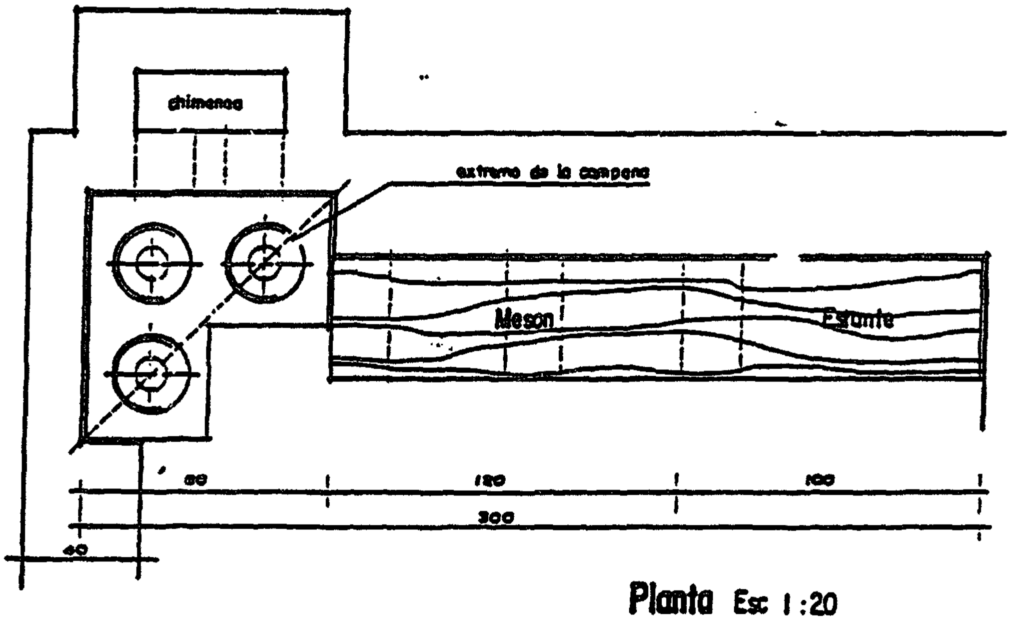
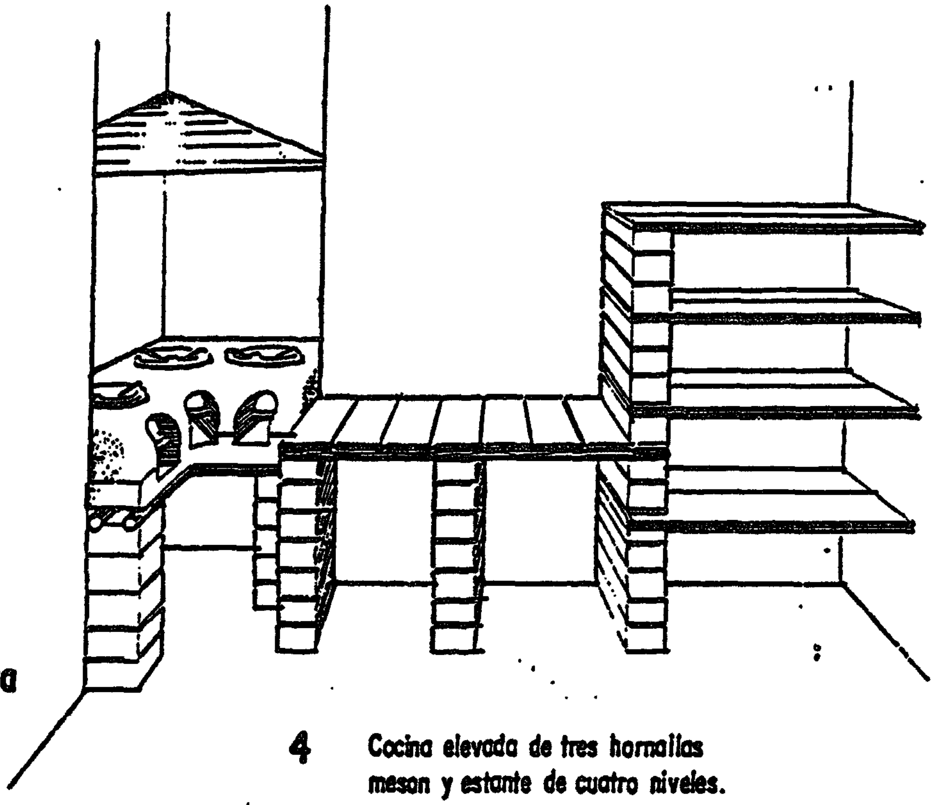


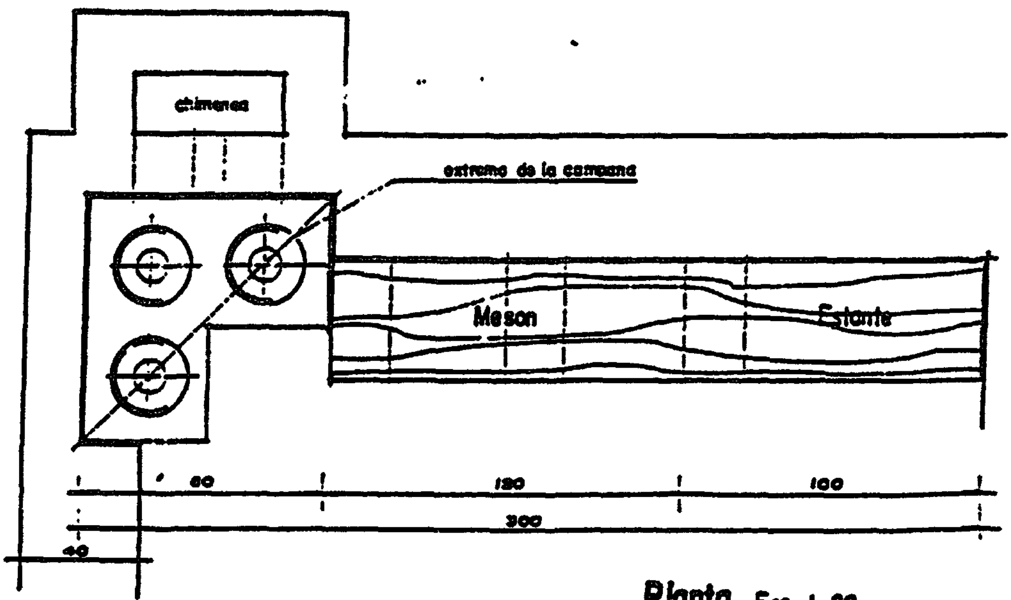
3 Cocina elevada de tres hornallas meson y estante de tres niveles.





Perspectiva

4 Cocina elevada de tres hornallas meson y estante de cuatro niveles.



Planta Esc 1:20

Annex VII: Experience in Bolivia with Reforestation Projects

1. Understandably, during the last 20 years, **reforestation** amounted to a mere 12,000 ha., most of which were planted with eucalyptus trees. While the thola in the Altiplano only has an annual growth of 0.2 to 1.4 tons per ha. left to itself or about 2 tons in a plantation, eucalyptus can provide 17 tons per ha. per year in plantations. With an investment cost of approximately US $70 per reforested hectare, an eucalyptus plantation can survive on a seven-year rotation, provided that it obtains a price of US$ 20 per ton of fuelwood in the local area. If the local community's alternative is to purchase LPG at a price of 1.1 Bs. (US$ 0.35) per kg, the use of purchased fuelwood for cooking leads to a cost-savings of about 40%.

2. During the 1980s, the most important reforestation activities were undertaken by COTESU in Cochabamba, Chuquisaca and Tarija. The results of reforestation activities in the Altiplano were disappointing, because of both climatic conditions and a hostile social environment -- the local population did not support the bilateral donor-financed projects. In 1990, FAO launched the "Tropical Forest Action Plan" with a budget of US$ 111 million for the 1990-95 period. One of the components, the US$ 9.6 million "wood and energy program," includes the establishment of fuelwood plantations in the Altiplano as one of its activities. The problem remains that the **social feasibility of reforestation projects for the provision of fuelwood** supply has not been proven. The Bolivian authorities have no proven concepts to rely on.

3. The efforts of forestry agents in the Altiplano are frustrated by what they perceive as the farmer's non-interest in tree cultivation. To cope with this, it is generally suggested that an awareness campaign must be implemented to convince the farmer of the importance of reforestation. Yet, while this is a necessity, it is not sufficient to cope with the problem. In the eyes of the farmers: (i) the number of days spent on fuelwood collection is too small to justify the effort in reforestation; (ii) the use of the time for alternative income generating activities may be more favorable; (iii) the waiting time for the harvest is long; and (iv) the restrictions on the access to the forested communal land through enclosures are perceived as a provocation. The campesinos are also unwilling to pay for seedlings, and if they get inputs free, experience has shown that they do not give priority to maintenance.

4. The implementation of reforestation projects is not a major problem. Once a public institution or an NGO has obtained bilateral funds to cover the operating expenses of the project, nurseries are established; plant experiments are conducted; educational materials are prepared; courses for campesino leaders and for extensionists are given; and a few hectares of trees are planted as a pilot project -- either fuelwood plantations, trees for multiple uses, or agrosylviculture. Usually a contract is made with the campesino community whereby the community provides the land and the manpower for the works. The men are paid in money; the participating women often in food.

5. Problems emerge when planting ends, and the planted area has to be protected against grazing animals. Control is difficult, and within a night, a year's work can be destroyed. Fencing is a technical solution, but has been resented by communities in the Altiplano as being against the principle of communal land. For social community projects to be sustainable, the community has to identify with the projects and find the efforts for forestry protection to be worthwhile. Few do, although some believe that the interest is increasing.

Annex VIII: Productive Demand for Electricity in Rural Electrification

1. The productive demand for electricity is a low percentage of total demand in rural electrification projects, but it can be an important determinant for overall project profitability:

(a) From the point-of-view of a utility, productive end-uses not only have the effect of load-building, generally they also augment the off-peak load.

(b) The marginal cost of investment for satisfying a larger productive demand for electricity is relatively low. Therefore, the cost of investment per kW of demand or kWh of consumption is decreased.

(c) The economic and financial viability of rural electrification projects depends on a rapid growth of demand which is a function of economic activity. A potentially large productive demand for electricity is an indication of rapid, local economic growth, and, thus, faster growth of rural incomes and electricity consumption levels.

2. Therefore, the existence of a productive demand for electricity is an important criteria for the selection of rural electrification projects by the regional development corporations and rural electricity cooperatives. Only areas that already have a basic infrastructure in place, such as access roads, are considered eligible for electrification projects. DINE approves only publicly-financed rural electrification projects where the productive demand makes up at least 50% of the total.

Table VIII.1: Productive Demand for Electricity

Commercial Electricity Demand in Huarina

Number	Activity	Kwh/Month
1	Health Post	52
2	Ice-Cream Making	275
1	Gas Station	266
1	Tire Repair	106
1	Hostel	107
1	Sewing Shop	50
1	Church	230
2	Bakery	91
1	Telecommunications C.	-
1	City Hall, Admin.	38
1	IBTA Facility	190
8	Stores	80
21		2,400

Source: Nyk Mano, et.al, Issues in Rural Electrification, ESMAP/MEH 1990

3. In rural electrification projects in other parts of the world, irrigation is by far the most important -- and often the most problematic -- rural user of productive energy. In Bolivia, this demand is met by diesel-powered pumps. Most of the productive demand takes place in the services and artisanal sector, which is not energy-intensive. The situation in the village of Huarina in the Altiplano depicted in Table VIII.1 is typical. The grid has 294 consumers and provides electricity to 21 commercial activities that consume 2400 kWh per month, or 114 kWh per activity. The demand of "campesino agriculture" for services is too low to create a higher demand for productive uses of

electricity. Since this type of agriculture is not mechanized, and ownership of cars is not widespread, there is little need for welding services, for example.

4. Historically, rural electrification in Bolivia has accompanied the development of mines. The energy demand of a mine provided the economic justification for the installation of a mini-hydro plant or a diesel unit; household electrification was a side benefit. It is much more difficult to do the reverse, i.e., meet the household demand for electricity and then to identify productive uses for electricity as a means to augment the financial and economic viability of the projects. Some rural utilities have tried to implement programs to promote the growth of productive demand as an integrated part of their electrification projects. Because of financial limitations, these efforts have had to be abandoned, and no promotion of productive use of electricity is presently undertaken.

5. In principle, the promotion of productive uses for electricity is beneficial. Since demand cannot be created artificially, the impact on electricity demand by a promotion program depends on the existence of a latent productive demand that is not realized because of the existence of barriers to its development. Barriers to productive electricity use can be of two kinds: barriers to finance, and barriers to information.

6. There are examples of rural electrification projects that did not achieve their goals, because farmers did not get the credits which they needed. Obtaining loans from the now defunct Banco Agricola was often a process that stretched for more than one year. By taking the financial needs of new production into account from the start of a rural electrification project, productive uses of electricity can be promoted. What is needed is: (i) to ensure that the feasibility study of the project includes an assessment of the financing needs of productive users that are likely to pose problems; and (ii) to make sure that the required amount for loan financing is included in the project budget. Such a "financial" promotion program should preferably be provided through the lead agency which is responsible for promoting rural development in the area. The conclusion is that rural electrification projects should be closely coordinated with the rural development programs in the affected area. In areas where such organizations are too weak, the program should be implemented by the utility itself.

7. Lack of access to information can also affect the productive rural use of electricity. Either existing producers in the region are unaware of the possibilities to increase productivity through the use of electricity, or some potential entrepreneurs are unaware of new services that can be created as the result of the introduction of electricity. The extent of this problem is unknown. But such information programs should be implemented by the utilities themselves, provided that a section of the utility has received prior training in their implementation.

Table VIII.2: Potential Productive End-Uses, Agroyungas Electrification Project

	Consumption kWh/month/ unit	Economic Benefit US$/month	Number of Units 1991	2020	Total kWh consumption 1991	Total kWh consumption 2020
Mines					%	%
Mine (large)	6,080	266	0	1	0	72,960
Mine (medium size)*	1,525	443	2	6	36,600	109,800
Subtotal			2	7	36,600	182,760
Agroindustries						
Fruit Agro-indu.	8,000	349	0	1	0	96,000
Animal Feed (mill, mix)	513	25	0	2	0	12,312
Coffee Mill	5,000	219	0	1	0	60,000
Grain Mill*	175	20	0	10	0	21,000
Small Canning Plant	100	7	0	3	0	3,600
Coffee Pulper*	46	24	50	198	27,600	109,296
Poultry Farm	171	10	0	3	0	6,156
Dairy Proc. Plant	60	176	1	3	720	2,160
Subtotal			51	221	28,320	310,524
Other Industries						
Sawmill	8,300	362	0	1	0	99,600
Carpentry (large)	200	11	1	3	2,400	7,200
Carpentry (small)*	100	24	6	28	7,200	33,600
Brick Factory	20	33	.	1	0	240
Subtotal			7	33	9,600	140,640
Services & Commerce						
Butcher's Shop*	240	13	0	7	0	20,160
Movie Theater	85	6	1	1	1,020	1,020
Video Showroom*	20	47	2	12	480	2,880
Ice Cream Parlor	700	33	1	8	8,400	67,200
Health Clinic*	700	212	2	3	16,800	25,200
Medium Size Hotel*	650	76	2	12	15,600	93,600
Tire Repair Shop	145	9	2	11	3,480	19,140
Mayachasita*	400	136	1	6	4,800	28,800
Small Office*	80	90	7	20	6,720	19,200
Hair Dresser Shop	32	3	3	10	1,152	3,840
Radio Station	4,000	176	0	1	0	48,000
Tailor's Shop*	45	16	10	29	5,400	15,660
Gas Station	153	9	1	3	1,836	5,508
Electronic Repair Shop	33	4	2	12	792	4,752
Welding Shop (large)	1,300	59	0	2	0	31,200
Welding Shop (small)	650	30	3	20	23,400	156,000
Large Store*	180	30	10	24	21,600	51,840
Small Store*	72	15	85	200	73,440	172,800
Subtotal			132	381	184,920	766,800
Public Lighting	700	33	10	30	84,000	252,000
Total			192	642	343,440	1,652,724

* An existing but not necessarily electrified activity.
Non-marked: New activities.

8. An examination of the data in Table VIII.2 suggests some tentative conclusions with regard to the prospects of utility-based programs for productive uses of electricity. The table presents a summary of the results of the demand study that was undertaken for the La Asunta electrification project in the Yungas. The total productive demand for electricity is the sum of the demand from the mines (11%), agroindustries (8%), other industries (3%), services and commerce (54%) and public lighting (24%) components. Before MEH launches a large donor-financed productive use of electricity promotion program, the approach should be tested in a small pilot project. The results should be evaluated independently and be used to define the most appropriate larger-scale program.

Annex IX: Estimates of Consumer Surplus in Rural Electrification Projects

Introduction

1. **The economic benefits of a rural electrification projects** consist of the benefits from: (i) household electricity consumption (usually at least 50% of demand), and from (ii) the productive demand for electricity.

2. The benefits of electricity for productive uses can be split up into two categories: the "energy value" and the "form value" of electricity:

(a) The "energy value" of electricity consumption is equal to the price a producer will pay for a certain amount of energy, either electricity or substitute fuels. It is equivalent to the cost of electricity plus the value of fuel savings if electricity substitutes for the consumption of higher cost fuels.

(b) "Form value" refers to the superior quality of electricity as a productive fuel. The introduction of electricity may lead (i) to increased productivity in production, (ii) to the production of higher value goods, or (iii) to the production of a new range of goods that depend on the availability of electricity.

3. The typical household in a rural electrification project consumes about 15 kWh per month. The electricity is used to power some 3 to 4 light bulbs and a radio. Most of this "base line consumption" is for lighting. Although the savings in expenditures on batteries for radio, TV and audio equipment can be considerable, the discussion of the benefits for rural households will concentrate on the consumer benefits from electric lighting.

4. The introduction of electricity in a household leads to the replacement of alternative sources of lighting: kerosene lamps, LPG lamps, diesel lamps, gasoline lamps, and candles. This has three effects on the consumers:

(a) compared to original lighting levels, the cost of lighting normally decreases;

(b) the quality of lighting increases; and

(c) the quantity of lighting increases.

5. The consumer benefits, therefore, comprise the value of the cost of replaced fuel, plus the value from the increased consumption of lighting in terms of quality and quantity that gives rise to a "consumer surplus".

Estimation of Lighting Consumption Levels

6. Quality effects cannot be taken into account in the economic analysis. Physical methods exist to establish the differences in the photometric characteristics of the luminaires (light sources = lamps). But to translate these, e.g., color differences, into quantitative economic terms is an arbitrary exercise.

7. The quantity effect can be expressed in a practical manner. The light emitted by a source is called **luminous flux** and is expressed in lux = lm. The luminous flux of a typical 60 Watt incandescent lamp, for example, is 730 lm. The consumption of light is expressed in kilo-lumen-hours, **klmh.** Thus, a 60W lamp during 4 hours of use produces 2.8 klmh. The energy efficiency of a lamp is called **luminous efficacy** and is expressed in how many lux per unit of power is generated: lm/W. The luminous flux of fuel based lamps depends on the individual quality of the lamp. But Table IX.1 below provides reference numbers that can be used in lighting consumption calculations.

Table IX.1: Lighting Quality of Lamps

Reference Figures for Lighting Consumption Levels

Luminaire	Flux lm	Luminous Efficacy lm/W	Power Rating W	Specific Fuel Cons. kg/klmh	Life of Lamp hours
Candle	12	0.2	70	1.3	-
Kerosene wick	40	0.1	400	0.8	4,500
Keros. press.	400	0.8	500	0.1	7,500
Gas mantle l.	500	1.2	360	0.07	7,500
Butane lamp	400	1.0	400	0.075	7,500
Fluorescent l.	900	0.6	14-18		6,000
Incandescent lamps	430	11	40		1,000
	730	12	60		1,000
	960	13	75		1,000

8. The quantity effect of a switch to electricity is larger, the larger the luminous efficacy of the electric lamp is compared to the substituted light source: 60 candles or 18 kerosene wick lamps or 1.8 kerosene pressurized lamps or 1.8 LPG lamps have to be used at the same time to obtain the 730 lm of a 60 W electric lamp. Obviously, this is not practical. In fact, while it is normal for a rural household to acquire 3 to 4 electric lamps (or just the bulbs), it is rare for rural households to have more than one kerosene lamp. Therefore, because of the technical characteristics of electricity, a switch to electric lamps leads an expansion of the consumption of light.

Calculation of Consumer Surplus

9. Data on fuel prices and daily hourly use of equipment in the area can be combined with the information of Table IX.1 to calculate: (i) average levels of fuel consumption for lighting and the monthly cost of lighting, and (ii) the average quantity of lighting that is consumed by each category of fuel consumer. The result provides a demand function for lighting. Table IX.2 shows an actual example from an Agroyungas rural electrification project in Asunta Valley in Las Yungas.

Table IX.2: Demand for Lighting in Asunta Valley, Yungas (average monthly figures per household)

Energy Source	Fuel expendit. US$/month	Consumption of light klmh	Price of lighting US$/klmh	Share of pre-electrification-consumers
Candles	6.75	3.54	1.71	30%
Kerosene	4.29	13.37	0.44	50%
Electricity	2.35	75.00	0.03	0%
LPG	1.94	96.75	0.02	20%

Source: UNDP/ESMAP, Rural Electrification and Demand Assessment in Asunta Valley, November 1990.

We see a classical demand curve -- the consumption of lighting is inversely related with price. 29/

10. The information of Table IX.2 is used to depict the demand curve of the area in graphic form in Figure IX.1. The theoretical concept is that there is one single demand curve for lighting, and that the four average price-quantity relationships each represent one point on this singular lighting demand curve. In theory, this curve is assumed to be continuous, as x-number of fuels are assumed to exist. Since we only have four fuels, the "true" demand curve for lighting is approximated by connecting the four points.

11. Figure IX.1 shows that the economic benefit of switching candle consumers to electricity is made up of three parts:

(a) (Area A) which represents the price of US$ 2.35 per month which they pay for their 15 kWh of electricity consumption;

(b) (Area B) which represents the monthly fuel savings of US$ 3.70 compared to their previous expenditures on candles; and

(c) (Area C) which is their "consumer surplus" of US$ 11.5, representing the difference between their "willingness to pay" (the total area under the demand curve) and the price actually paid for electricity minus (to avoid double-counting) the value of the fuel savings.

12. The economic value of electrification for kerosene and LPG consumers is arrived at in the same manner. For LPG consumers, there is a little complication. In the project above, the unit lighting cost using LPG is actually lower than for electricity. Therefore, according to the demand curve, an LPG consumer who switches to electricity will decrease his consumption. Strict application of welfare theory shows that this switch will make him worse off: a consumer welfare loss equal to the little triangle under the demand curve between 75 and 96.75 is involved (see Figure IX.1). A switch, however, only makes sense if the higher comfort of electricity compensates the consumer for the higher fuel price. This is assumed in the calculation of the economic benefits for LPG consumers shown in Table IX.3.

29/ There is "a lack of concensus among the experts as to the interpretation of this demand curve for lighting and the conclusions derived from it of estimates of consumer surplus. The authors of the report view this curve as a lighting demand curve, while other experts consider it to be merely a plot of unit fuel costs against monthly household use of four fuels for lighting at different levels of consumption and expenditure and not a demand curve".

Table IX.3: Economic Benefits of Rural Electrification by Origin (US$/month)

	fuel exp. savings	consumer surplus	elec. cost	% elec. contr. to total house average		
Candle	3.70	11.50	2.35	17.55	30	5.27
Kerosene	1.94	3.95	2.35	8.24	50	4.12
LPG	0.42	0.42	2.35	2.35	20	0.47
Average	2.00	5.60	2.35	9.95	100	9.95

13. What conclusions can be drawn from Table IX.3? The first is the **importance of incorporating consumer surplus into the economic analysis calculations of rural electrification projects.** They represent:

(a) 65% of the economic benefits in the case of candle consumers

(b) 48% of the economic benefits in the case of kerosene consumers

(c) 18% of the economic benefits in the case of LPG consumers

14. Far too often, only the fuel savings and the financial cost of the tariff are included in the benefit side in rural electrification studies. The result is an underestimation of the true economic benefits. This is unfortunate. During the 1980s, support for rural electrification projects declined among energy economists and among donors. During the 1970s, rural electrification projects had been promoted based on their supposed impact on economic development in the region. As the expected creation of new economic activities did not take place, it soon became clear that electrification per se is not an engine of economic development. The disappointment with the productive impact of rural electrification, and the high financial cost of rural electrification projects per connected household led many donors to scale down their financial engagement in rural electrification projects.

15. The previous overselling of rural electrification benefits led to this skepticism which was shared by many energy economists. Rural electrification projects were considered non-economic. Some argued that electrification was not high on the priority list of the rural population. The projects were welcomed because no alternative investment proposals were presented to the rural population. Others tended to regard the pressure of the rural population for electrification projects as non-rational.

16. While there is some truth in these arguments, the conclusions deserve to be qualified in the light of the results of the consumer surplus calculations presented in the methodology. The welfare gains to the households are large.

17. The second conclusion is that the **connection rates should be financed via credit subsidies.** Unless electricity is made accessible to low income consumers, the full potential of economic benefits from household electricity consumption will not be realized:

(a) If all three consumer categories have the same connection rate, the average benefit per connected household will be US$ 9.95 per month.

(b) If none of the candle consumers can afford the US$100 connection rate, the average benefit per connected household will drop to US$ 6.56.

18. The credit for the connections can be recuperated through higher tariffs. Let us assume that connection is provided free, and that the utility wants to recuperate the amount within five years through monthly charges that are added to the electricity bill. If a 10% interest rate is demanded, the monthly charge would be US$ 2.12. This is less than the fuel savings obtained by the candle consumers and close to the fuel savings of the kerosene consumers.

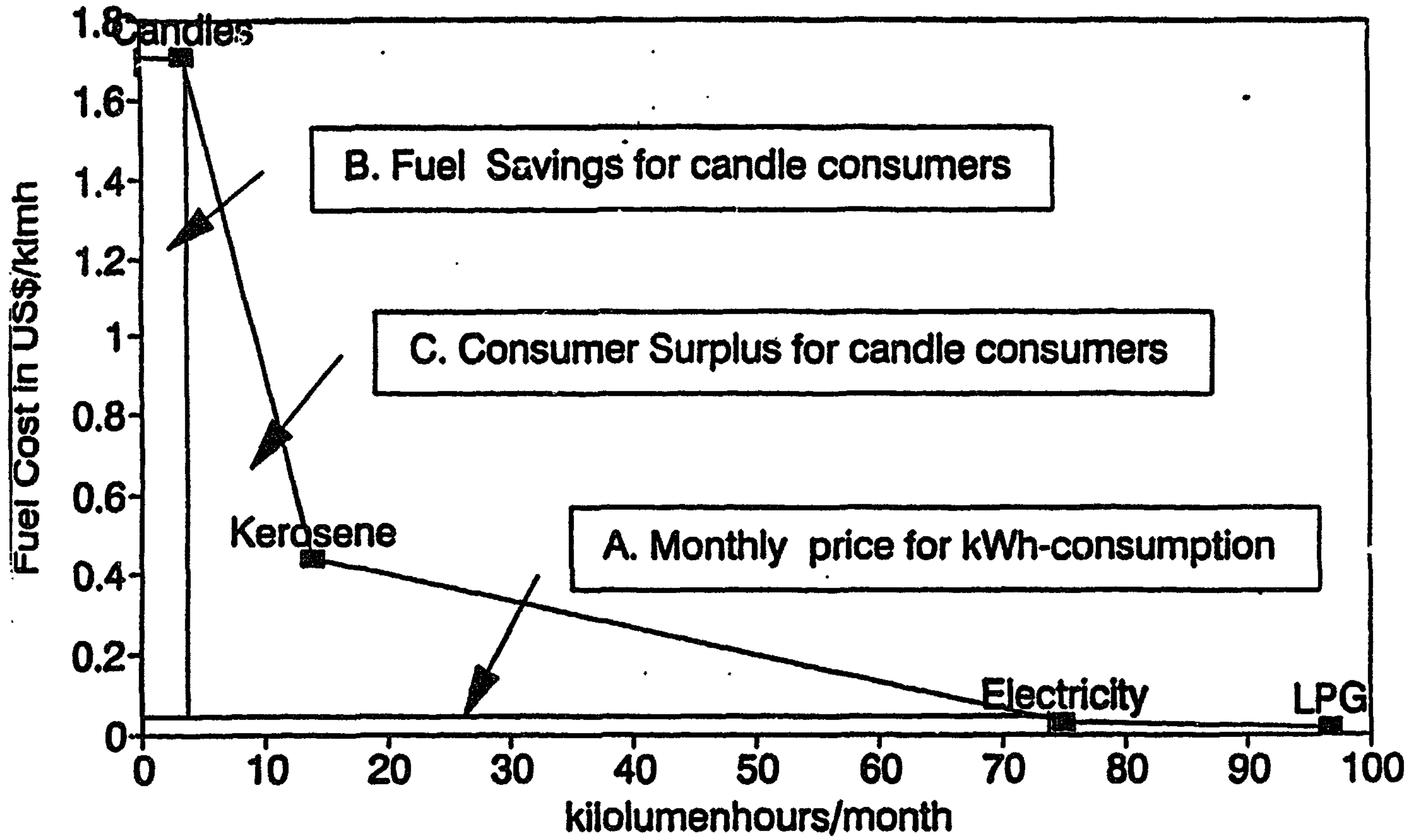
19. The power company can recuperate the connection subsidies in two ways: (i) through a monthly base charge per connected household; or (ii) through an increase in the electricity tariff. The second possibility implies an implicit subsidy of low-income consumers, as higher-income consumers have higher consumption levels. It also offers the advantage to the utility that the subsidy is recuperated faster--often average demand rises over time.

20. The above figures of the Bolivian electrification project are incomplete, as only fuel costs are taken into account in the analysis. A more complete analysis would take into account the amortized cost of equipment as well. Average life times for lamps are given in Table IX.1, information on equipment cost can be obtained from the field survey.

21. A good demand analysis that comes close to estimating the actual consumption (kW-h) and demand levels (kW) can be an important saver of financial resources: it can justify appropriate investments in generating capacity and in the distribution system, e.g., to vary the size of the line conductors in proportion to actual load carried.

DEMAND CURVE FOR LIGTHING

Economic Benefits from Electricity



Annex X: Rural Income and Credits in Bolivia

Rural Income and Debt Capacity Levels

1. The consumption of LPG and of electricity requires investments in equipment (and in connection costs) and leads to monetary operating costs during use. Only a minority of rural households has an income which is high enough to cover these expenditures in the light of other priority demands. The level of income is a major determinant for the market of any energy technology. It determines the cash flow for "petty" investments like LPG stoves, and the debt capacity or annual amortization capacity for "major" investments like the household connection to a rural electricity grid or the purchase of a water pump for irrigation.

2. The average income per capita of US$ 250 in rural Bolivia is lower than the average income in urban areas, which in La Paz is US$ 855. The distribution of rural income is as skewed as the urban incomes: the three categories of rural poor who in Table 10.1 make up 70% of the rural families have a 12% share of rural income. Based on an estimate of the maximum savings capacity for each income category of household, Table X.1 makes a gross estimate of the annual payments the different categories of rural households can make to amortize a debt.

Table X.1: Rural Family Incomes and Debt Capacity
Year: 1989

Condition	Number of families (1000)	Aver. Inc. per person US$	Aver. House-hold income US$	Amort./ income ratio	Annual amort. capa-city, US$	Total Debt capacity US$ *)
Extr. poor	131	90	505	0.05	25	125
Very poor	197	160	900	0.10	90	450
Poor	131	250	1,400	0.15	160	800
Middle	131	450	2,500	0.20	500	2,500
Rich	53	3,000	16,650	0.35	6,000	30,000
Very rich	13	25,000	140,300	0.35	50,000	243,000
TOTAL	656	250				

* Assuming that an investment loan has to be repaid over 7 years at 10% interest. Source for income figures: Calvin Miller, Evaluacion del Credito Rural en Bolivia, ESMAP/MEH, June 1990

3. Based on these figures, the total debt capacity for each income category of households is indicated. These figures show how much outstanding debt a rural household can take on, and still be able to comply with the amortization schedules of the loans. The figures indicate the order of magnitude of the size of investments that are relevant for different categories of households. Any market study for rural technologies must take these levels into account. The conclusion is that the range of technological options that can be offered to the three lowest income groups (70% of the rural population) is very limited. The debt capacity of this population is in the US$ 125 to US$ 1,700 range. Since needs other than energy have to be attended, only energy technologies that cost a fraction of this amount (maybe a third) can find a market in this section of the rural population, i.e., relevant energy technologies have to be in the US$ 40 to 550 range.

4. The above methodology for the estimating debt capacity deserves two words of caution. First, the income estimates lump together monetary income and income in kind (basically the value of the self-consumption of own production). For the low income groups, monetary income is a fraction of total income, but it is from this fraction that amortization payments must come. Second, the debt capacity figures provide a static picture. The capacity to take on debt as evaluated by a financial institution will include an evaluation of the rate of return for the intended investment. If the investment generates a flow of funds that is sufficient to more than cover the amortization, the debt may be increased beyond the amounts shown in Table X.1.

5. In practice, this extension of the debt capacity concept is more relevant for the commercial farmers than for the poorest 70% of the farmers. Particularly in the Altiplano, it is frustratingly difficult to identify investment opportunities for campesino farmers that yield commercial rates of return. Also, although the observation is relevant for productive energy investments, it does not affect the debt capacity for household energy investments, such as the payment for an electricity connection.

Rural Informal and Formal Credits 30/

6. Debt ability defines the potential rural demand for credits which by some is estimated to be as high as US$ 400 million per year. This estimate may be on the high side. But the availability of credit is another structural determinant for the market prospects for commercial energy technologies in rural Bolivia. **Formal credit institutions**, such as the Development banks Banco Agricola and FINDESA, established by CORDECRUZ, are the most important source of financing for the commercial farming sector. But few "campesino farmers" are able to make use of their credits; for these the most important source of finance are loans provided by private persons. 31/ This use of informal sector credits is a rational response to the characteristics of the rural economy. The banks need collateral and tend to be relatively inflexible in insisting on amortization schedules that may not correspond to the harvest dictated cash flows of the campesino farmers. The numerically largest demand is for loans below US$ 400 for which the informal loan sector is the most competitive source of supply. 32/

7. From the individual campesino's point of view, the informal sector loans have the disadvantage of high interest rates. Therefore, as an intermediate form of formal sector credit, credits provided to individual farmers through rural credit cooperatives have shown to be the most

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30/ The content is based on the information provided in the report by Calvin Miller, Evaluacion del Credito Rural en Bolivia, ESMAP/MEH, June 1990.

31/ In a case covering 699 families living in the three Southern departamentos, during the year only 25 had made use of formal credit institutions, while another 569 would have been interested in doing so.

32/ A case study in Cochabamba revealed that the average rate of interest on informal sector loans of 48% was much higher than the average 13% rate of formal sector bank loans in the rural sector. The average US$ 4.35 cost of transaction for informal sector loans, on the other hand, was much lower than the US$ 136 for formal sector loans. Based on these costs, the point of cost indifference for the size of formal and informal sector loans was US 376.

attractive way of organizing rural credits. 33/ On average they are larger than informal sector loans, whereas formal credits are generally eight times as high. FENACRE (Federacion Nacional de Cooperativas de Ahorro y Credito), and ICI (Institucion de Credito Intermediaria) channel some US$ 11.5 million per year to some 160 cooperatives and provides technical assistance. Their policy is that cooperative members must have some savings in their account in order to be eligible for a loan. 34/

8. During the 1980s, rural NGOs became an important facilitator of credits to the poorer sections of the rural population. They are not credit institutions, but within their areas of operation, they tend to provide an integrated package of services to their target group including loans by establishing "fondos rotatorios". The provision of credit filled a financial gap that was created by the breakdown of formal rural credit during that period. But the risk is that some NGOs take a paternalistic attitude to the provision of credit. Instead of promoting participatory credit schemes, they give "non-restricted" loans with paternalistically low interest rates in order to promote narrowly-defined project goals.

9. The FDC (Fondo de Desarollo Campesino) was created by the state in 1990 as a state alternative to formal sector loans. The FDC has three functions: (i) to provide credits for investments in production and in infrastructure, (ii) to coordinate institutional efforts, and (iii) to attract financial resources. The intention is to finance "integrated rural development" schemes through subcontracts with NGOs. Three types of credit will be provided: (i) "pure" credits for productive investments with good rates of return; (ii) credits combined with subsidies for infrastructure investments and for technical assistance; and (iii) subsidies for development projects in marginal areas. The concept is interesting. It makes use of the existing structure for support in rural areas, the NGOs, and avoids the use of subsidized credits on a general basis.

33/ A case study of rural cooperative credits in Santa Cruz determined transaction costs of US$ 20 for credits with an average length of 12 months.

34/ Rural credit cooperatives, that as a prerequisite for a loan, require members to establish a savings account and save a certain amount over time, have the lowest rate of defaults.

Annex XI: Options for Isolated Systems - Dentro Thermal Power Plants

1. Dentro-thermal power plants of 3 to 4 MW are a potential but not realistic possibility for the generation of electricity in rural areas. The idea of generating power by using wood grown in dedicated, short-rotation tree plantations is sensible. Wood combustion technology is well established. Using managed plantations would enhance rather than deplete forest resources. The system would use an indigenous, renewable energy resource and, being labor-intensive, provide employment opportunities in rural areas.

2. Feasibility studies were made for a US$ 10.3 million 3.5 MW plant in Trinidad and a US$ 1.4 million 1 MW plant San Ignacio. Of the total investment cost for the Trinidad plant of US$ 10.3 million (US$ 2,940 per kW installed), 76% were foreign exchange costs. The cost of the power plant was US$ 6.7 million (US$ 1,910/kW), other investment costs included reforestation, logging, road construction, and project administration. Total operation, maintenance, and administration costs were estimated at US$ 5 million during the first eight years of operation, and US$ 10.7 million for the other 15 years. Plant efficiency of 22%. Assumptions were that one m^3 of wood can generate 2.56 MWh and that 1 ha. yields 26 m^3. For the San Ignacio plant, the key assumptions were that the total investment was US$ 1.4 million; operation and maintenance cost estimated at US$ 100,000 per year; plant efficiency 12.5%, wood cost of US$ 15/ton; yield per ha. 25 m^3 annually.

3. The costs of production were estimated at about US$ 0.16 per kWh. This is not cheaper than the production cost of diesel powered units, but still puts the plant in the competitive range with diesel power plants. In practice, however, the concept has several weaknesses, as shown by the experience in the Philippines' large program that started in 1979: of the 17 projects originally planned, only six were completed; and in 1990 only one was operating on an intermittent basis. The establishment of reforestation schemes based on mono-cultures has proven to be questionable in the Amazon areas. The plant requires extensive maintenance and cleaning. Extensive support must be given to the rural electrification cooperatives in planning, designing and implementing these generation plants. The conclusion is that dentro-thermal plants should not be part of energy planning during the 1990s. The potential advantages do not offset the weaknesses: (i) they do no assist in the key issue of cost savings, and (ii) the risk of technical failure is high.

Annex XII: AREAS WITH FAVORABLE MINI-HYDRO POTENTIAL

Status Quo of Mini Hydro Power in Bolivia

1. The development of smaller hydropower plants began at the turn of the century. By 1950, 47.6 MW were installed. These plants were mainly developed by the private sector to provide electricity for mines and urban usage. There has been little development of smaller hydropower units in the past 30 years due to a number of factors including, the increased use of natural gas generated electricity, the high cost of traditional smaller hydropower plants, and the decline of the private sector. With the 1985 reforms there seems to be increased possibilities of a strengthened private sector, within which smaller hydro plants may have a role if their costs can be reduced, and low load factors improved.

2. The opportunities for low cost hydropower projects in the country seem to be promising for locally-developed projects. Three different organizations are confident that mini and micro hydropower projects costing $1000/kW (or less) are possible. To date, two such projects have been completed (La Suerte by PTF and Chaco by Plan International), a third plant is under construction, and another organization (IHH) believes that higher head plants can generally be developed in the Yungas and nearby areas for approximately $1000/kW. Such costs are possible using projects developed by local entities formed by those who will later use the energy. Such organizations can take the form of small local cooperatives, users' organizations or local entrepreneurs.

3. Pursuing a least-cost rural electrification strategy typically means grid extension to those areas that are economically feasible, and either illumination with LPG or kerosene, or remote generation in the isolated areas. The energy supplied by the grid would be electricity generated from natural gas or larger hydropower plants that were competitive with natural gas generation. Electricity for the rural areas would be higher either generated by diesel or hydropower, depending on cost. Those smaller hydropower plants located within range of grid extension would have to have an energy cost (depending on location) at the lower end of the range, while those remote sites distant from the grid could have higher energy costs.

4. Given the realities of many of the rural areas of Bolivia of small widely dispersed communities, micro sites offer advantages over larger sites. Most communities will not be large enough to furnish adequate demand for mini size plants, and generally most communities will be too dispersed to furnish a demand center that can be economically serviced. The micro site located close to its demand center will avoid the substantial transmission costs that are likely to be incurred by larger sites with insufficient local demand.

5. There is potential for the growth of a domestic hydropower industry in the country, with demonstrated talent in turbine design and testing, project construction and management, and hydraulic modeling of proposed projects. Such development needs to be further encouraged and assisted and hopefully expanded through the development of supportive institutions for administration and finance.

Resource Availability

6. The area with the most natural resource potential for successfully using mini-hydro technology for rural electrification would appear to be the Eastern Valleys and the Andean slopes shown in Figure 5. The entire area extends along the front of the eastern ranges, has a width of 100-200 km, a length of 1,000 km and extends from near the Peruvian border to southeast of Tarija. In area it is about 14% of the country.

7. The rivers best situated for the development of mini-hydro are along the eastern sides of the Andes, at elevations of 1000 to 4000 meters in the northeast part of the country, extending over an area of approximately 50,000 km², or 5% of Bolivia. The area which appears most favorable, based on precipitation patterns, would include the basins of the following rivers (from north to south); Tuichi, Copani, Consata, Chiniso, Tipuani, Challana, Zongo, Coroico, Undiavi, La Paz, Choquetanga, Inquisivi. These rivers are all tributaries of the Rio Alto Beni and are likely to have good flow characteristics, as the mountains generally are higher to the north and have more snow and ice to supply the upper basins. Another potential area for development is found further south, to the east of Cochabamba. The area has elevations of up to 4500 meters and is drained by the Rio Chapare.

Potential Rural Demand

8. Given the area of resource potential of approximately 14% (or 5% if we consider the optimum part) of Bolivia, what is the **demand for electricity** within this area? The area is thought to have a considerable need for energy, but has little infrastructure. There also is potential for promoting productive uses in the general area for forestry, mining and agriculture. The northern part of this sector has shown considerable promise for mining, especially for goid in the basins of the Rio Mapiri and Rio Tipuani, and also contains the Yungas, an area with considerable agricultural potential.

Community Demand

9. The density of inhabitants per square kilometer in the **northern part** of the area with favorable hydroelectric resources are 5-15/km², while in the **southern part** of the area densities are also generally 5-15/km², except in parts of the southern areas where 15/km² is typical. Given the typical income levels, these densities mean that no rural electrification is likely to be possible except in a limited coverage basis for communities of substantial size, and for locations with productive uses.

10. No studies or information were available for the Mission on a regional basis for the area except for the department of **Santa Cruz**. A study done by CORDECRUZ indicates that 100 diesel generators in 51 different locations service 70 communities with a total population of 104,000, and a total demand of 9.8 MW. 35/ For the other areas of interest, it was necessary to attempt

35/ CORDECRUZ, Ing Ibert Cruz, 1985, Energia Electrica En El Area Rural De Santa Cruz.

an estimate from other sources, to determine if sufficient demand existed to warrant a need for a program of smaller hydro power projects.

Productive Demand

11. Mines and sawmills are substantial loads. Some sawmills require 500 kW (with an average of 100-200 kW), and a typical mine with three drills will use 120 kW, or more than 20,000 kWh/Mo. Thus any mine, or sawmill with residential consumers is likely to require a mini sized plant. Potential application for micros can be found in some of the coffee producing and processing areas.

12. PTF has received a number of requests of assistance from mining cooperatives to evaluate potential hydrosites in their areas. Of the requests, four are listed to show the potential electrical demand they represent:

(a) Coop on the Rio Consata began in October 1988 with fuel costs of $4,000 month.

(b) Coop located near Tipuani where one liter of diesel = 4Bs ($1.60), and fuel costs have been $172,000 for 2 years.

(c) Coop near Tipuani on Rio Kewichero. A potential site nearby has a head of 100 meters and a flow of 150 l/s, for a potential of 100 kW. One liter of diesel fuel = $1.30 liter, fuel cost for one year = $18,198.

(d) Mine near Sorata where potential demand is 150 kW and fuel costs are $10,000/month

13. Thus it seems probable that substantial productive loads from mining activities exist in the general area of these rivers. It is not known how many other gold producers are working in the area. A demand survey needs to be made (if it has not already been done) and the possibility of mini hydro power sites should also be studied. Then an analysis of the least-cost method of bringing energy to these mines could be determined by an analysis of the different options (grid, local hydro power, or a mixed scenario). A note of caution, in at least one country, Ecuador, alluvial gold mining operations were moved too frequently to justify the construction of a hydropower plant.

14. It has been estimated that there is a total of 350-400 sawmills in the country; with 240 in the department of Santa Cruz, 30 in La Paz, 25 in Tarija, 20 in Beni and 20 in Cochabamba. Most of the sawmills are powered by diesel generation and the waste wood is not used for energy generation. Most sawmills in the departments of La Paz and Beni are near rivers, some of which may have potential hydropower sites nearby.

15. Additional areas where hydro potential could be exploited to supply smaller systems are:

(a) The area northwest of Sucre, along the upper tributaries of the Rio Grande and Pilcomayo. The geology of this area is likely to be quite favorable for recharge of underground supplies.

(b) Small basins that have the glacial debris of the Zapla formation, should offer highly favorable recharge characteristics; these basins are likely to be only in the micro range.

(c) Basins that drain the low mountain ranges of the Brazilian Shield in the department of Santa Cruz.

16. These areas may be in regions that are being considered for grid extension.

Total Demand in the Optimal Area

17. The annexed figure shows the distribution of population centers ranging from 100 to 2,000 people (using 1976 data). If a population growth of 2.6% a year is assumed, the population of these centers has increased by 43% to the present. The map shows an approximate grouping of these centers into 6 arbitrary areas. In the **north** there is 1) an area east of Lake Titicaca, 2) one in the vicinity of Coroico and Chulimani, and 3) one in the area of Inquisivi. In the **southern half** of the favorable resource zone, there are also three areas. The first is around 4) Cochabamba, others are in the high valleys between 5) Sucre and 6) Santa Cruz, and 6) one is in the vicinity of Camiri and Montegeudo.

18. Of the six zones, three may be logical candidates for possible grid extension, since the grid is present. However, within these areas there may be considerable potential for **micro sites**. A study by CORDECRUZ described a substantial number (101) of sites in the region. 36/

19. The three areas outside of the grid extension range may be considered further. The southernmost area (high valleys) is an agricultural area that has both less rainfall and forests and mining than the northern area. The two areas in the north appear to have considerable potential for mining, forest industries and agriculture.

20. In the three areas, there are over 60 communities of 150-1,000 people and 6 communities of 2,000 people. Using 4.3 people per household (MEH) and 150 watts per use, the smaller **communities** could used 20 kW and the larger about 100 kW. It may be possible to find several of the smaller communities close enough together to require a mini-sized plant. Assuming that 33% of the communities are close to a suitable site there could be about **20 micro sites and 2 mini sites**. An assumption is made that there are **enough mines and sawmills to require 5 to 10 mini sites**, and that possibly **1-2 small sites** may be needed. In addition, it may be reasonable to assume that there are **small communities of 50-100 people**, which could use 5 kW. The result would be:

36/ CORDECRUZ, 1981, Estudio De Viabilidad De Pequenas Centrales Hidroelectricas, Vol. 2.

Number of Schemes	Size	Average Capacity kW	Total Capacity kW
1-2	Small	1000	1000
5-10	Mini	200	1000
20	Micro	20	400
10	Micro	5	50
Total: 26-32			2450-4450

21. How reasonable are such assumptions? A study done by CORDECRUZ found a total of 171 hydro sites in the department of Santa Cruz. For the 7 provinces with the best hydro potential (and no grid extension) there were a total of 104 communities with populations of 15-1,000 (average 303). Approximately 50% of these communities were found to have a hydro site nearby (distance unknown). If we assume that 50% of these sites are economically feasible, there would be 26 micro sites of approximately 20 kW in size. Thus the estimate of 20 micro sites for communities seems reasonable.

22. For the optimum areas then it is realistic to assume that about 35 projects can be developed within the next 15 years provided that financing is available. If a cost of $1,000-$1,500 per kW is used, there would be a total cost of $2,175,000 for 1450 kW.

Total Demand in the Rest of the Country

23. Within the rest of the country there are likely to be many areas with small streams that may be developed economically, even in areas near the grid. Given the less favorable precipitation in much of the country west of the favorable zone, the percentage of demand centers that could be matched with a hydro site would be quite low. But, it seems reasonable to estimate that another 20 projects could be found, although the costs of these projects would be higher.

Total Demand/National Demand

24. Adding up the various prospects it can be estimated that the potential may exist to develop 100 micro (less than 50 kW capacity) and 10 mini-sites (less than 1000 kW capacity) in isolated rural areas in Bolivia, over a period of 10-15 years, providing a total installed capacity of 3.5 MW and rural electrification for 40,000 people.

25. Considerable potential may exist for the rehabilitation of older plants which are no longer in operation. The total number of these plants and their installed capacity is unknown, but it is substantial, since one source lists seven sites with a total capacity of 19.8 MW as candidates for rehabilitation. Occasionally such sites can be restored to operation for only $150-250/kW, if problems with the civil works are not significant. Therefore, a program of locating the non-operational sites and assessing their restoration costs should receive high priority.

26. While the total cost of a project is very important in the general level of energy costs, an equally significant factor is the load factor. The effect of increasing the load factor can be seen between the projects of La Suerte and Chaco (Table XII.1), where an increase of 53% leads to a 33% reduction in energy cost for a project that has a capacity which is 9% lower. The effect is more pronounced when both projects are compared with a 30 year lifetime; then the energy costs are reduced from US$ 0.104 kWh to US$ 0.038/kWh.

Table XII.1: Comparison of Load Factor and Energy Costs for Three Low Cost Hydropower Sites

Project	Capacity	Load factor	Capacity Cost	Energy Cost
La Suerte	130 kW	0.26	1044 $/kW	0.7 $/kWh
16 October	250 kW	0.37	720	0.024
Chaco	20	0.17	1150	0.104

Annex XIII: Assessment of the Potential Role of Wind Power in Bolivia

Status Quo of Wind Energy Development in Bolivia

1. Approximately 100 wind turbines have been installed in Bolivia, primarily for water pumping for irrigation. Several of the turbines are installed in the area of Santa Cruz, but some turbines are also erected in Oruro and La Paz. The projects are primarily undertaken by non-governmental organizations.

2. Approximately 30 turbines for water pumping have been installed at **Santa Cruz**. The first turbine was installed in 1971. According to the manufacturer, the turbines operate without problems. The turbines are the multi-blade type and the rotor diameter is 3.5 m. Hub-height is approximately 20 m. The manufacturer is Riva Palacios, located in Menonita.

3. In the area of **Oruro**, the Programme for Self Development of Farmers (Programma de Autodesarrollo Campesino (PAC)), is operating as a NGO, financed, inter alia, by the European Economic Community. The programme includes different agricultural projects for communities and cooperatives, including installation and operation of wind turbines for water pumping for irrigation purposes. Until now, 20 turbines have been installed since 1980. 70% of the turbines are paid back by the farmers during a two or three year period. The major part of the turbines are manufactured by Cadenas Andinas S.A.M. (CASAM). The turbine is multibladed with a rotor diameter of 2 m. The cost of the turbine is US$ 1,200 according to the manufacturer.

4. In the **area west of La Paz** the Servicio Múltiple de Technología Apropriada (SEMTA) has manufactured and installed 15 turbines on experimental basis. According to SEMTA, the manufacturing costs are US$ 1,000 for a 5 m rotor diameter.

5. Projects related to **Research and Development** within the field of wind energy technology are limited. The R&D activities are mainly concentrated on development of small wind turbine concepts for battery-charging and household supply.

6. At the Technical School of San Alonso in Santa Cruz, studies on small electricity producing wind turbines for battery charging are carried out. The projects are mainly performed by the teacher at the metal workshop assisted by a few students. General knowledge of wind energy technology at the school is limited. The small turbine for household power supply is two bladed.

7. A development project for small power producing wind turbines for household power supply is initiated by SEMTA and tested under real application conditions in a pilot project.

8. In Huachacallo, Oruro, the Centro Piloto de Educación Rural (CIPER) are experimenting with a 3.5 m rotor diameter turbine for water pumping.

9. **No monitoring of the wind energy activities** in Bolivia has been made and no data regarding power performance and reliability of the existing turbines are collected. No specific wind

measurements have been made to evaluate the wind resources in Bolivia. Only general meteorological data and data from airports is available.

Potential Applications for Wind Power

10. In a broad perspective wind power can only play a marginal role in meeting the energy demand in Bolivia. **Grid supply** can be ruled out as a possibility in the Bolivian context. Developments can only take place in a small part of the country's rural areas. The relevant turbines are small, low-cost, simple construction turbines with rotor diameters up to 5 m.

Household electricity use for lighting and radio/TV is an interesting application. But further developments are needed before the potential role can be defined. But the rather large wind variations over the year and the frequency of calm periods will set technical limits for the application of household turbines. The installed cost of these systems--about US$ 650 to 750--further restricts the market to the relatively few remote farmers who have the financial ability to acquire the system.

11. In the case of **cattle watering**, wind turbine pumping from groundwater could provide drinking water in remote areas where other sources are scarce. The most promising use of wind turbines is for the pumping of **water for irrigation** purposes. To estimate the potential market the ground water resources and quality as well as farm topography has to be known. These factors will restrict the market for wind technology.

Estimation of Market Size

12. The size of the comparatively limited market for wind turbines in **rural energy supply** for irrigation and household electricity use will, inter alia, be dependent on the wind regime, the wind turbine cost, and the benefits obtained by the farms and households. A large number of physical and economic factors have to interact positively, thus limiting application to a small percentage of farmers.

13. Because of their wind regimes, the most promising areas are certain regions of Santa Cruz and Beni. In addition, some locations in the Altiplano have wind regimes that permit the application of wind energy.

14. In the central part of the Santa Cruz Department, the energy density of the wind during the irrigation period is sufficient to make wind energy a competitive energy option for water pumping. Approximately 22,000 farm households are located in the Santa Cruz Department. An estimated 10.000 are located in areas with adequate power density.

15. Provided that an active wind power development programme is implemented, a rough estimate of the potential market for turbines for **irrigation** is approximately 1500 wind turbines over the next 5-10 years or **150-300 wind turbines** per year. A rough estimate of the demand for household electricity turbines is 500 wind turbines during the next 5-10 years or **50-100 wind turbines** per year.

Impact of Wind Energy on the National Energy Balance and the Economy

16. Even under optimistic assumptions, the potential contribution from wind power 10 or 20 years from now will hardly be noticeable in the total energy budget (0.5-1.0 per mille of total energy demand in terms of toe). The impact on the economy will depend on: (i) the savings compared to diesel powered irrigation, (ii) on whether in extreme cases the application of wind energy permits irrigation to take place which otherwise would not have been possible, and (iii) on the cost-savings of household electricity generation systems based on wind power compared to diesel/gasoline generator or photovoltaic-based systems.

17. The following socio-economic aspects have to be taken into account during a comparison of water pumping by wind pumps versus diesel/gasoline driven pumps:

Wind turbine characteristics:

* Wind turbines can be locally manufactured, and most repairs can be done by local artisans in the rural areas making the technology appropriate for even remote areas.

* The necessary maintenance is simple and infrequent and spares can be made available from the local producers.

* Small foreign exchange cost component.

* Relatively high investment cost and low O&M costs means that the single farmer will need assistance for financing for instance through NGOs or via agricultural credit facilities. The cost structure means that once the windmill is established the average farmer with low income will not experience recurrent problems of financing purchase of diesel oil.

Diesel engine characteristics:

* Diesel engines are relatively complicated to manufacture and some specialized knowledge is necessary to make repairs, thus making the technology less appropriate for remote areas.

* Regular maintenance is necessary and spares can only be obtained from dealers.

* The diesel supply could be unreliable in remote areas due to lack of regular distribution system.
* The cost of diesel oil may at a future stage become a foreign exchange item seen in a national perspective as oil resources are modest (reserves to production ratio estimated to 12 years in 1983). Further, competitive uses in transport and industry may cause sharp cost increases.

* Relatively low investment costs and high running costs means that the single farmer in some years may have serious difficulties in providing the cash for purchase of diesel oil.

Experiences with Irrigation in Bolivia

18. Irrigation investments have had a mixed record in Bolivia. Recent assessments have shown the following factors as being important for the success of irrigation projects. First, small scale is essential--no large scale irrigation scheme has succeeded. Second, community involvement is essential. Third, follow-up assistance in improved farming methods and marketing can substantially increase the net returns. Fourth, net benefits vary negatively with the altitude of the area.

19. The National Service for Community Development (SNDC) has implemented 39 small-scale irrigation projects in the Highland and Valley regions. The costs per hectare range from \$18 to \$229,407 per hectare and from \$2 to \$376 per beneficiary depending on the system applied. Detailed ex-post evaluations have been carried out on two of these projects which highlight some of the factors which influence the impact of the investment.

20. The first project is located in a community of 250 people on the road from Potosi to Sucre. A \$17,000 investment in irrigation increased the irrigated land in production by 152% and the annual yield by 203%. However, family income was only 32% higher in 1989 than when the project was initiated in 1982, far short of project goals. Increases in transport costs and lower prices offered by the intermediaries reduced the benefits of the surplus generated. In addition, because of the limited size of the local economy, production increases forced down prices fetched in the local markets. The project had not considered the context of commercialization and market absorption.

21. The second project is located in an isolated community in the department of Oruro which survives on a very limited base of potatoes and livestock, mostly llamas. Due to weak technical implementation and miscalculation of available water resources, production increased only 26%. Family income remains unchanged due to unchanged low productivity, and few market opportunities. No crop diversification resulted since the community is isolated from any technical assistance in agriculture and was not rained during project execution for the expanded opportunities afforded by irrigation.

22. A recent evaluation 37/ of 558 micro-irrigation projects in La Paz, Oruro, and Potosi reached positive conclusions. The report stresses the importance of community involvement throughout the project cycle starting with identification. Communities often identified projects, participated in construction, and organized themselves to maintain the projects. Some problems were found in the technology chose. There is a strong need to balance the limited knowledge of

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37/ "Informe de la mission de evaluacion de proyectos de desarollo agropecuario y microriego en los departamentos de La Paz, Oruro, y Potosi;" MINPLAN, MACA, UNDP, and Swiss and Netherlands' Technical cooperation, May 1989.

the communities in project implementation with the need for hydrologically sound investments. Most of the irrigation projects did not change farming methods in the affected areas, due to lack of follow-up with extension and other services -- similar to the individual experiences of SNDC cited above. Even without changes in technology the benefits were substantial in reducing the variability of the amount harvested. Some examples show double benefits with extension and irrigation, compared to irrigation alone. The cost-benefit ratio calculated at a discount factor of 12% p.a. showed positive net benefits for 93% of the projects in terms of area irrigated. The net benefits very inversely with the altitude of the project area. 38/

23. The lessons from past projects show that to increase the efficiency of irrigation investments, more attention needs to be placed on the commercialization of production and other post-harvest activities, the development of integrated packages including agricultural extension and credit information, and on community involvement. Technical problems in many small-scale irrigation projects point to the need to refine site analysis procedures and types of technology selected.

38/ From gross benefits of US$200/ha at 4,000 m and higher to 3500$/ha in areas below 3,000m.

Annex XIV: The Regional Energy Planning System in Bolivia

The Planning Hierarchy

Responsibility at Ministerial Level

1. In principle all public investments have to be accepted by the **Ministry of Planning and Coordination** (MPC). Energy investments which are mainly electricity investments have to be approved by the MPC which requests the MEH to confirm whether a given project is in accordance with the current energy policy and plans. If the MEH and the MPC give their approval, the MPC will approach the international loan market in order to procure the loan. A minimum rate of 8% will be charged to the borrowing agency.

2. DINE (the Ministry's office for electricity) and COFER (the Ministry's agency for rural energy development) are supposed to ensure the vertical coordination of rural energy activities. DINE has a series of governing functions, including the responsibility for the approval of investment projects for new grid systems for electricity distribution when these are carried out by publicly-owned organizations. DINE always requires that: (i) there has to be a market in which at least 50% of the electricity can be used for productive purposes, and (ii) that the costs involved in the supply of electricity in the new area must be covered by the sales revenue. There is a gap, however, between the intentions of DINE, and the practical possibilities of enforcing these intentions. If a local organization is able to raise funds, even for a project which does not fulfil the DINE criteria, in many cases, DINE is not able to stop the project. Neither is DINE able to stop projects, which are carried out by a regional development corporation (RDC), if the project is financed by means of the RDC's own financial resources. COFER never received the financial resources that it needed to play a constructive role in project implementation 39/; its ability to influence rural energy planning was diminished by its location outside the ministry. When a RDC contemplates a large-scale power project as part of a regional development initiative such plans nominally are to be supervised by COFER and coordinated with ENDE development plans, but frequently neither entity is consulted. Currently COFER acts as a consultant for energy projects (mainly rural electrification) that are implemented by other organizations.

The Regional Development Organizations

3. The RDCs represent the policies of the Central Government and are responsible for the social and economic development of their departments. In order to fulfill these responsibilities, the RDCs have to elaborate and implement plans within the different sectors, energy, education, health, etc. These plans have to be coordinated at a national level by the Ministry of Planning and Coordination. The RDCs receive the various national plans and programs from the MPC in order to implement these regionally. An RDC can establish instruments of aid and consultancy in order to coordinate public programs with the programs of non-governmental organizations.

39/ The monthly salary budget for COFER's staff of 24 persons is US$ 3000, which makes it impossible to maintain staff for longer periods. In 1990, 50% of COFER's staff had been employed less than 12 months.

4. The RDC system gives rise to two kind of problems. The first is the issue of equity: the different financial and administrative capacities of the RDCs. Most of the income comes from fees on, e.g., the production of raw materials in their territory. Since minerals are unequally distributed in the territory, some RDCs have much higher incomes than others. Several RDCs have virtually no financial resources of their own. Consequently, they continue to be overly dependent on scarce and unreliable TGN support and central government micro-management. The four Departments with the lowest per capita income, Oruro, Potosi, Beni and Pando comprise 20% of the Bolivian population, yet only 8% of the total annual amount which is invested by the nine RDCs is placed there. In the Department of Oruro, CORDEOR invested US$ 1.8 per capita in 1988, whereas CORDECRUZ invested US$ 16.4 in the Department in Santa Cruz.

5. The **financial inequity** is felt in rural electrification. The relatively prosperous Santa Cruz and La Paz Departments have established rather favorable loan conditions for electricity projects, that are evaluated as feasible. If village dwellers desire electricity, they are requested to form an electricity distribution cooperative. CORDEPAZ requires the cooperative to finance 20-40% of the material costs, and finances the remaining 60-80% through soft loans. During the construction phase CORDEPAZ pays for administration, transport of labor and material, and the wages of the site workers. It is possible for members of the cooperative to pay a part of the 20-40% by themselves working on the site. All in all, the support of CORDEPAZ amounts to a subsidy of between 20-35% of the total. If, however, an electrification project is not linked to the electricity distribution grid and not located in the Department of Santa Cruz or La Paz, it can have financing problems and may have to pay 18-20% annual interest on dollar-denominated loans.

6. The **administrative inequity** is felt in regional energy planning. Some RDCs, such as CORDEPAZ and CORDECRUZ have the capacity to establish a regional rural energy planning and implementation process. CORDECRUZ's Planning and Project Unit, for example, has 99 employees of which 42 have a higher education. Three of these are allocated to the field of electrification, and occasionally three others, from the Engineering Division, are involved with electrification. Both RDCs have produced electrification plans for some specific areas. Other RDCs either do not have the capacity for energy planning or have not realized their potential in this area. CORDECO, the RDC for Cochambama, for example, does not consider the energy sector in its plans. The electricity planning is considered the responsibility of ENDE and the electricity distribution company, ELFEC.

7. The second problem for energy sector planning is the **poor coordination between regional and national initiatives due to a lack of a clear definition of RDC coordination of sectoral projects**. RDC coordination of the planning of the range of agricultural institutions in their departments is difficult within the existing structure. MACA has regional offices in each department which report directly to its headquarters in La Paz. In addition, seven affiliated agencies have independent planning units over which the RDC has no formal control. Thus, while the RDCs are responsible for coordinating departmental planning, they have little authority to do so. In practice, coordination is function of the goodwill of parties involved. As a rule there is an inverse relation between the degree of RDC dependence on La Paz for technical approval or funding and the ease with which a project passes from design to execution.

NGOs

8. Within the private sector, the institutions with the greatest capacity for providing extension services to remote areas have been the non-governmental organizations (NGOs). Although the NGOs have a tendency to cluster around the rural areas in the immediate vicinity of the larger urban centers, they have had an increasingly visible profile in rural Bolivia and their impact on the poor has been quite impressive in certain areas. Many external funding sources viewed NGOs as viable alternatives to reaching the poor and provided support for their activities. Donors often deal directly with them for funding projects in the agricultural sector and basically ignore the central ministries. During the 1980s, the scope of the NGOs involvement in the implementation of rural development projects gradually became much more important than the execution of projects by government institutions.

9. There are three general types of NGOs operating in Bolivia: (i) religious organizations, (ii) international private voluntary organizations (PVOs), and (iii) national NGOs, or private development institutions (PDIs). The **church** has been active for the longest period and has a large infrastructure in health and education. The **international PVOs** focus their activities in a number of clearly delimited geographical areas, and generally seek to provide integrated basic services including health care, education, water supply and sanitation, and agricultural development. **PDIs** are extremely heterogeneous. Most operate small projects in rural development with an emphasis on community education and participation. Many have a political or ideological edge honed during the years of dictatorship in Bolivia. Recently, PDIs have begun to form associations and networks along sectoral, geographical and thematic lines.

10. A distinction must be made between the most serious and professional organizations -- able to manage large amounts of funding for local energy planning and rural energy projects -- and the galaxy of small and short-lived NGOs with little or no professional capability. The former can offer valuable experience and replicable planning methodologies if a clearer institutional context is set up and their specialization is utilized.

11. NGOs can bring the following strengths: (i) detailed knowledge of local conditions, (ii) experience in community development, (iii) a willingness to experiment with non-traditional forms of service provision, and (iv) staff commitment to poverty alleviation. Greater efforts should be made to ensure that these strengths can be effectively combined with those of government and community groups. The weakness is that NGOs do not have any responsibility for setting priorities for their activities. They have become important sources of employment and provide salaries for their staff that usually are higher than public sector salaries. It is, therefore, in their economic interest to expand or maintain their level of activity. One can notice a tendency to mass produce project proposals with the hope that one of them will be within the area of interest of a donor. The outcome (i) may not reflect that the genuine priority needs of the target groups are addressed, but that activities of secondary importance are carried out, and (ii) that the administrative expenses of the NGO make up a very high share of the individual project budgets.

Political Representation at "Grass Root Level"

12. Small projects with active participation of the poor communities and a consensus approach to decision-making appear to be the most effective in promoting development for "campesino" farmers. Although the results of such projects may be positive for the beneficiaries, their number is frequently so reduced that the overall impact is minimal. Success would then appear to depend on support of a large number of small effective projects and ensuring that these efforts are closely coordinated so as to avoid duplication of effort, or even worse conflicting objectives of different projects.

13. The government's professed shift to heavier reliance on free-market signals and private sector initiative implies that the clientele in question -- Bolivian farmers -- must be furnished opportunities to have their concerns heard, to have a say in setting funding priorities, and to contribute as partners in the overall process of rural policy formulation. Policy analysis and planning require experienced staff who cannot only evaluate the potential impact of different policy alternatives on the macro economy, but who can also help leaders in the farm and rural sectors identify common goals and define the means to take action.

14. Participation from the rural and agricultural sector has two weaknesses at the national level. First, the farm community is not organized in a uniform, formal manner across the country. There is no official form of representation or delegation of authority with defined limits. Second, participation implies considerable travel costs and investment of time. This has been a severe constraint to organizing producer associations at the national level.

15. In each region, however, the representation of the farm community has been accommodated in a few committees and boards where the public and private sectors cooperate. The types of organizations that represent farmers vary significantly among regions, ranging from cooperatives to chambers to peasants' unions. As farmers become more organized, these varied forms of representation are becoming more proactive. This is, however, a gradual process which is still in its early stages of development. The creation of the Peasant Agricultural Development Corporation (CORACA) is an indication of changing attitudes among campesinos. Yet, despite the apparent effort to create a depoliticized, technical campesino organization, the increasingly independent political postures of peasant unions and parent organizations makes the future of CORACA and other such organizations uncertain. Without mobilization and generation of their own resources, any institution is unlikely to succeed as an independent and autonomous entity. Some producer associations are run by small farmers with the assistance of NGOs. These often coexist with unions and other communal institutions, but are maintained strictly as technical and economic (as opposed to political) institutions. Farmer cooperatives have been promoted over many years by NGOs and international donors, although severely limited scope and coverage have generally been the result.

B. Organization of Rural Electrification

16. Rural power grid or off-grid electrification is provided primarily by distribution concessions (under municipal law) or cooperatives. Power is either purchased from ENDE's grid

and routed through one of its distribution substations, or it is generated by small isolated plants operated by ENDE or a cooperative/distribution company itself. Rural electrification through grid extension is to some extent done by the eight main distribution entities other than COBEE (La Paz) and ELFEFEC (Cochabamba) which supply power principally to urban areas. Several isolated systems are found throughout the country principally serving smaller urban areas (Tarija, Trinidad, Cobija). The largest, Trinidad, is run by ENDE. In small towns and rural areas, numerous communities operate distribution concessions or cooperatives run independent systems (diesel, micro and minihydro) with capacities ranging from 20 kW to 1000 kW. A number of these systems serve or have served mining communities in the Altiplano and Valles.

17. Electric cooperatives can gain legal status by being registered with the national cooperative institute, INALCO. INALCO is the regulating body for all cooperatives in Bolivia. The greatest benefit of being registered with INALCO, in addition to the legal status conferred, is that import duties are waived on equipment purchased from foreign vendors. There are more than 100 small electric cooperatives in Bolivia, of which 90 are in the department of Santa Cruz (Tropicos). In addition to the large, urban-based CRE in Santa Cruz; sizeable and connected cooperatives include CORELPAZ, a 12,000-member cooperative in the Altiplano; CEY, a 4,000-member electric cooperative in the Yungas; and CESSA in Sucre.

18. Once operational, many decentralized systems face financial difficulties. Tariffs are not sufficient to cover costs, forcing many top depend on RDCs for subsidies. The financial situation sometimes is exacerbated by poor institutional management. Smaller systems often do not have the resources necessary for basic preventive maintenance and repairs, and prefer to reserve their scarce funds for emergency situations.

Annex XV: Simulation of the Cost of a LPG Lamp Promotion Program

Cost of Lamps US$ 40

User Participation	1992	1993	1994	1995	1996	1997	1998	1999	2000
New consumers 200,000 kero. users	31,250	28,125	25,313	22,781	20,503	8,453	16,608	14,947	13,452
120,000 candle users	18,750	16,875	15,188	13,669	12,302	11.072	9,965	8,968	8,071
Total	50,000	45,000	40,500	36,450	32,805	29,525	26,572	23,915	21,523
Existing 700,000 LPG users	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000	20,000
Kero. replacements	0	0	0	15,652	29,688	28,719	31,869	36,486	32,837
Candle replacements	0	0	0	9,375	17,813	16,031	19,116	21,892	19,702
Number of Lamps	140,000	130,000	121,000	162,900	200,610	184,549	195,094	204,585	188,126
Investment	5,600,000	5,200,000	4,840,000	6,516,000	8,024,400	7,381,960	7,803,764	8,183,388	7,525,049
Loans=80% of cost	4,480,000	4,160,000	3,872,000	5,212,800	6,419,520	5,905,568	6,243,011	6,546,710	6,020,039
Repayments	1,280,000	2,468,571	3,574,857	4,424,229	5,024,091	5,563,968	6,049,857	6,258,585	6,020,039
Net Loans	3,200,000	1,691,429	297,143	788,571	1,395,429	341,600	193,154	288,125	0

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 - Out of Print)	05/89	--
	Francophone Household Energy Workshop (French)	08/89	103/89
	Interafrican Electrical Engineering College: Proposals for Short- and Long-Term Development (English)	03/90	112/90
	Biomass Assessment and Mapping (English - Out of Print)	03/90	--
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 - Out of Print)	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
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
	Power System Efficiency Study (Out of Print)	12/87	--
	Power Sector Efficiency Study (French)	02/92	140/91

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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	--
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 (Out of Print)	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 - Out of Print)	02/87	--
	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English - Out of Print)	11/87	--
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
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
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

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Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
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
	Energy Assessment (English and French)	07/91	8017-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
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
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
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
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 - Out of Print)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
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	--
	Industrial Energy Efficiency Technical Assistance (English - Out of Print)	08/90	122/90
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

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Uganda	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 - Out of Print)	03/89	UNDP Terminal Report
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
	Petroleum Management Assistance (English)	12/89	109/89
	Power Sector Management Institution Building (English - Out of Print)	09/89	--
	Charcoal Utilization Prefeasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM

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
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
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
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 - Out of Print)	--	--
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84

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Vietnam	Rural and Household Energy - Issues and Options (English)	01/94	161/94
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
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-Out of Print)	05/86	--
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English - Out of Print)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English - Out of Print)	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
Western Samoa	Energy Assessment (English)	06/85	5497-WSO

SOUTH ASIA (SAS)

Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program	05/83	002/83
	Status Report (English)	04/84	015/84
	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Prefeasibility Study (English - (Out of Print)	12/88	--
India	Opportunities for Commercialization of Nonconventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	05/91	120/91
	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
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 - Out of Print)	05/88	--
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
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

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	EUROPE AND CENTRAL ASIA (ECA)		
Eastern Europe	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
Portugal	Energy Assessment (English)	04/84	4824-PO
Turkey	Energy Assessment (English)	03/83	3877-TU
	MIDDLE EAST AND NORTH AFRICA (MNA)		
Morocco	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
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
	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
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English - Out of Print)	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	--
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	--
	National Energy Plan (Spanish)	08/91	131/91
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Prefeasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Houshold Rural Energy Strategy (English and Spanish)	01/94	162/94
Chile	Energy Sector Review (English - Out of Print)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	--
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	--
Ecuador	Private Minihydropower Development Study (English)	11/92	--

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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-Out of Print)	03/88	--
	Energy Efficiency Standards and Labels Phase I (English - Out of Print)	03/88	--
	Management Information System Phase I (English - Out of Print)	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
Panama	Power System Efficiency Study (English - Out of Print)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English- (Out of Print)	09/85	--
	Status Report (English and Spanish)	09/85	043/85
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English - Out of Print)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	--
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Trinidad and Tobago	Energy Assessment (English - Out of Print)	12/85	5930-TR

GLOBAL

	Energy End Use Efficiency: Research and Strategy (English - Out of Print)	11/89	--
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	--
	Women and Energy--A Resource Guide The International Network: Policies and Experience (English)	04/90	--
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	--
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93

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