Report No. 4213-BO

Bolivia: Issues and Options in the Energy Sector

April 1983

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BOLIVIA

ISSUES AND OPTIONS IN THE ENERGY SECTOR

April 1983

ACRONYMS AND ABBREVIATIONS

Acronymns

M	Thousand
MM	Millions
B	Billion
bbl	Barrel
BD	Barrel per day
CF	Cubic Feet
TCF	Trillion Cubic Feet
MMBtu	Million of British Thermal Units
T	Tonnes
TCF	Trillion Cubic Feet
KW	Kilowatt
MW	Megawatt
GW	Gigawatt
LPG	Liquid Petroleum Gases

Abbreviations

ANICARVE	National Association of Industrialists for Charcoal Production
CDF	Center for Forestry Development
CORDECH	Development Corporation of Chuquisaca
ENDE	Empresa Nacional de Electricidad (Power)
GDC	Gas Development Corporation
INER	Institute for Rural Electrification
MEH	Ministry of Energy and Hydrocarbons (Hydrocarbon Companies)
NIS	National Interconnected System
PERTT	Executive Program for Soil Rehabilitation in the Department of Tarija
YPFB	Yacimientos Petroliferos Fiscales Bolivianos

CURRENCY EQUIVALENTS

Currency Unit	Bolivian Peso ($b)
Official Rate	$b 200/US$

FUEL EQUIVALENTS

(Gross values: As used by Bolivian MEH)

Product	Unit	Sp. Gr.	Kcal/kg	MMBtu/Unit
Crude Oil	bbl	0.745	11,507	5.409
Natural Gas	MCF	-	-	1.045
LPG (Liquid Petroleum Gas)	bbl	0.550	11,834	4.107
Motor Gasoline	"	0.700	11,612	5.129
Aviation Gasoline-800	"	0.700	10,401	4.594
Naptha	"	0.775	11,500	5.624
Kerosene	"	0.798	11,112	5.595
Jet Fuel A-1	"	0.807	11,762	5.989
Diesel Oil	"	0.800	11,112	5.609
Fuel Oil	"	0.850	11,112	5.960
Other Fuels	"			5.500
Ton of Oil Equivalent			10,000	39.683
Lubricants		0.88		
Asphalt		1.05		
Fuelwood	kg		3,500	
Charcoal	kg		7,480	
Bagasse	kg		1,800	
Electricity				
Generation	Mwh			11,377
Consumption	Mwh			3413

This report is based on the findings of an energy assessment mission which visited Bolivia in January, 1982. The members were Ms. Ursula Weimper (Mission Leader), Takashi Takayama (Economist), Andres Liebenthal (Economist-Conservation Specialist), Luis Luzuriaga (Power Engineer), William Beattie (Forester), Charles McPherson (Legal Specialist), Can Toktar (Reservoir Engineer), E. Mariani (Mechanical Engineer, Consultant), T. Ritter (Geologist, Consultant). Secretarial assistance for this report was provided by Mrs. Angelica A. Fernandes and Mrs. Josefina Regino-Suarez.

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I. SUMMARY AND RECOMMENDATIONS

Overview

1.01 Bolivia has a large energy resource base ($1230x10^6$ TOE) relative to its present internal needs ($1.9x10^6$ TOE). The hydropotential is by far the largest known resource, but only 287 MW of a total potential of 18,000 MW have been developed. Its hydrocarbon resources 1/ consist mostly of natural gas (some $6.7x10^{12}$ CF or $176x10^6$ TOE) and a more modest amount of oil and condensates ($187x10^6$ bbls or $25x10^6$ TOE). The modern Bolivia economy is based on liquid fuels, which currently supply almost four-fifths of commercial energy requirements. Natural gas has been recently introduced and its share is still less than 10%. Incremental demand of commercial energy will have to be provided through a balanced development of gas and hydropower production, transport and utilization facilities, in such a way that the domestic and export market potential can be achieved while minimizing the strain on the country's borrowing capacity. These options are evaluated in Chapters 3, 4 and 5.

1.02 The available options to increase energy supplies will have to be complemented by a massive program to assist energy users to increase the substitution of gas for liquid fuels, to reserve the scarcer liquid fuels to priority uses where their value is highest and to increase the overall efficiency of energy use. The essential condition to stimulate this substitution process is the pricing of the individual energy forms at a level that reflects their opportunity costs. In addition, this will require an active and carefully directed program of demand management.

1.03 The rural population of Bolivia still relies mostly on fuelwood for their energy needs. In the Altiplano, this population suffers from a century old shortage of fuelwood which has contributed to its total deforestation and substantial degradation of its soil. This has also extended to the adjacent valleys, which are now largely denuded, especially near the traditional mining areas of the southern Altiplano. Although the improvement of this situation must be supported by a long term program of reforestation and utilization of agricultural wastes, the energy issue cannot be considered in isolation from integral rural development and long range agricultural resettlement policies. Some of the possible initial steps are presented in Chapter 6.

1.04 Overriding these energy problems, Bolivia faces a critical balance of payments disequilibrium that has paralyzed the country and threatens future growth prospects. This makes it urgent to evaluate the energy sector's capability to increase foreign exchange earnings; present gas exports to Argentina already provide 30% of these earnings. (Chapter 8).

1/ Includes proven and probable reserves.

Gas Export Project to Brazil

1.05 A long-standing proposal for a gas export project to Brazil is currently being negotiated. The decision to go ahead depends on the certification of sufficient reserves and on the agreement of a mutually acceptable price for gas.

1.06 The mission has evaluated the data on gas reserves and considers that on the basis of present information on the resource base, there are sufficient grounds to be confident that the new export commitment can be satisfied. A reserve evaluation study, shortly to be contracted, will provide further guarantees.

1.07 The exportable gas surplus has been estimated on the basis of internal requirements over a 30-year period (2.7-3.1 TCF) and the existing gas export commitment to Argentina (0.8 TCF). The internal demand is estimated under an extreme scenario assuming that final energy requirements would grow at 4% p.a., that oil supplies would decline by 2% per year and that incremental power requirements would be gas-generated. It has further been assumed that Bolivia would build in the 1990's a commercial sized ammonia-urea complex and possibly a plant to convert gas into methanol or gasoline, and operate these plants over 20 years (Table 8.1).

1.08 The gas export project to Brazil is based on a supply commitment of 400 MMCFD or 2.9 TCF over 20 years. If reserves of gas are substantially less than the present estimate for proven (5.0 TCF) and probable reserves (1.7 TCF) or if exports to Argentina continue after 1991, there could well be a supply gap. Therefore, appraisal activities to prove up reserves in known fields and intensive exploration to discover new resources must take place in the event the export project is implemented. On the other hand, 30% of the internal estimated gas requirements correspond to power generation, which could alternatively be supplied through a carefully balanced hydropower development program.

1.09 The price negotiations are crucial for the export project and difficult because of the present oil surplus in international trade and because of Brazil's efforts to restructure its internal energy market. In principle, the two governments had agreed in 1978 to price the gas in terms of the thermal equivalent of the liquid fuels to be replaced in the Sao Paulo area. In the short term, this means that the gas will be related to the price of industrial fuels, mainly fuel oil. There are several possible interpretations to this agreement (paras 8.7), and they produce an estimated price range for gas of US$3.67-5.30/MCF 1/ in Sao Paulo and a border price range from US$2.30-3.92/MCF in 1982 dollars. This compares with a current border selling price to Argentina of US$4.27/MMBtu.

1.10 The large price ranges indicate the difficulty of reaching a favorable agreement. At the lower end of the price range, the project would not cover Bolivia's long term economic costs, considering that the

1/ For gas with calorific value of 1010 Btu/CF.

production and transport cost of gas to the border is US$1.65/MCF 1/ and that the incremental capital cost of switching to hydropower is equal to some US$0.94/MCF. Another aspect to consider is the net effect on the trade balance. Even at the lower price, the project would generate an increase of about US$200 million in net foreign exchange earnings, assuming that the project's cost (US$800 million) will be financed through international loans and repaid during the first ten years of the project. Other elements to be taken into account in the negotiations are the security of supply which this project would provide Brazil and the contribution that gas would have on the air quality of Sao Paulo.

1.11 The mission also reviewed gas conversion processes (ammonia-urea and liquefaction to methanol and gasoline) and found that at present neither of these provide a realistic alternative to direct gas exports. These projects have a poor rate of return, in some cases even negative net back values for gas, because the domestic market is too small to provide a reasonably guaranteed scale of production and the international market has a high risk because of the excess supply likely to occur during the second half of the 1980's.

1.12 However, there exists a real possibility of industrial complementarity between Brazil and Bolivia. Both governments agreed in 1978 to enter into joint ventures for processing gas. On the basis of this precedent, the mission strongly recommends that Bolivia continue to explore the joint development of a fertilizer and/or a methanol plant with Brazil. (See Chapter 8 for details).

Domestic Market

1.13 In 1981, Bolivia consumed internally about 2.8 MMTOE of primary energy and exported 1.9 MMTOE. Natural gas exports to Argentina represented 98% of the exports, the rest consisted of LPG, gasoline and naphthas. The internal demand structure is described in Table 1.1 below.

1/ Assumes an average transport cost between Santa Cruz and the Bolivian-Brazilian border of US$0.62/MCF and a production cost of US$1.03/MCF.

Table 1.1: 1981 Bolivia's Domestic Energy Market Structure

GROSS SUPPLY			NET DEMAND		
Source	000'TOE	%	SECTOR	000'TOE	%
Biomass	987	35	Industry	419	20
Hydro	310	11			
Oil	1100	39	Mining	64	3
Natural Gas	441	15			
TOTAL	2838	100	Transport	660	31
Intermediate Demand	351	12.4	Residential/ Commercial	1002	46
Statistical Adjustment	342	12.1			
Final Consumption	2145		Final Consumption	2145	100

Source: Annex 1.14

1.14 The long range projection of future energy demand is particularly difficult for Bolivia because the energy sector and the economy are undergoing major transitions. In order to provide an analytical basis on which to assess policy options, three alternative demand scenarios were developed. These were based on the assumption that economic recovery would be slow until 1985 and that thereafter the economy would grow on an average rate of 5% per year.

A. Oil Deficit

1.15 Projections of oil supply and historic demand trends indicate that a supply deficit of over 13 MBD equal to 40% of the demand for oil products will occur by 1990. This will exacerbate the qualitative imbalance which Bolivia already faces between the refinery yields and the type of products demanded by the market (Para. 4.11).

1.16 The mission recommends a three-pronged approach to avoid the long term oil deficit: (a) supply-oriented investments to compensate for the rapidly declining oil production and so postpone the onset of a major oil deficit; (b) investments in gas transport to substitute for oil; and (c) demand management measures, including pricing policies, to induce energy users to change their pattern of consumption and use energy more efficiently.

1.17 The mission proposes, as a minimum objective by 1990, the reduction of Bolivia's dependence on oil from the current 77% to 55% of total final commercial energy consumption, compensated by increased direct use of natural gas and of LPG derived from gas (Table 1.2).

Table 1:2 Recommended Change in Pattern of End-Use Commercial Energy Consumption
(%)

Energy Forms	1981	1990
Oil derived products	77	55
Gas derived LPG	9	23
Natural gas	4	10
Electricity	10	12
Total	100	100

Investment in Increased Oil Supply:

1.18 The investment requirements to maintain an adequate supply of liquid hydrocarbons for the domestic market have been estimated at US$440 million (1980 prices) during the period 1982-1990. During the first years, emphasis should be on the development of already discovered condensate fields and on enhanced oil recovery projects. Some of these projects have already been delayed and their further postponement would lead to an unmanageable oil deficit by 1985. The mission fully supports the early implementation of the Vuelta Grande development project, and suggest that other recently discovered fields, such as Tacobo and Montecristo, be evaluated. Similarly, the mission supports YPFB's endeavours to obtain financing for the Monteagudo and La Pena secondary and tertiary recovery projects and for the LPG extraction plant at Vuelta Grande. It further suggests that feasibility studies for enhanced recovery projects be made for the oil fields of Caranda, Camiri, and Cambeiti, which still contain significant amounts of oil (Chapter 3).

1.19 The actual proven reserves-to-production ratio for liquid hydrocarbons is close to a minimum acceptable level (12 years). Therefore, exploration efforts during the first period should be concentrated on defining the extensions of the fields already discovered and confirming the existence of probable oil and condensate reserves. The prospects of finding new oil fields in conventional structural traps are modest and only stratigraphic traps offer the potential for large additional resources although the exploratory risk is high. YPFB has an interest in initiating this type of risky exploration activity, but the mission considers that while this program may be economically justified it should be postponed to the second half of the decade unless private companies are willing to take most of the risk (para 3.14).

1.20 It is the mission's opinion that the results of the negotiations with Brazil do not affect crude and condensate production, because it is less dependent on the expansion of the gas market than originally thought. The already developed condensate fields provide the bulk of present oil and gas production. During the next 10 years oil production from these fields can only be sustained if gas is reinjected to achieve maximum recovery of liquids. Consequently, their net gas production will increase slowly. During this time, new export commitments will have to be supplied from new and mostly dry gas fields, developed specifically with that objective, and these do not contain large amounts of liquids. This opinion must be validated by a detailed reservoir engineering study for each field with a large gas production potential. Such a study will also provide the basic input for an optimization model, required to program the orderly development of Bolivia's hydrocarbon resources.

Investment in Gas Pipelines:

1.21 The Altiplano region uses 90% of the fuel oil and 60% of all petroleum products consumed in Bolivia. Therefore, this region must be the prime target for substitution by gas. There are two separate pipeline projects for the Altiplano with a total investment cost estimated at US$170 million. The first (US$130 million) is a new line from Santa Cruz to Cochabamba and the reconversion of an existing oil pipeline to extend the service from Cochabamba to Oruro and La Paz. IDB has approved a loan for this project, which would have an initial capacity of 33 MMCFD and a final design capacity of 90 MMCFD. 1/ The second project resulted from an emergency decision taken by YPFB, induced by the delay in the disbursement of the former loan. This project is to extend the existing southern Altiplano line Monteagudo-Sucre not only to supply Potosi, but also Cochabamba and connect there with the reconverted line to Oruro and La Paz. This line (US$40 million) is planned to have a gas carrying capacity of 25.7 MMCFD.

1.22 The simultaneous construction of both projects will result in an initial excess capacity in Cochabamba of 39 MMCFD 2/ and in high transport costs. On the other hand, the capacity of the southern emergency line will be fully used by 1985, thus limiting the substitution process in the following years. In view of the investments already made in the expansion of the Monteagudo-Sucre line, the mission recommends that this line be completed and that the decision on the new Altiplano pipeline be postponed to 1985-86, when the market trends become clearer.

1.23 The mission considers that the project to build a pipeline network in the Tarija department is not justified at this time.

Demand Management

1.24 There is scope for energy and, specifically oil, conservation in all sectors of the Bolivian economy, but main emphasis should be placed in the transport and industrial sectors, including in the latter metallurgy and the energy sector itself.

1.25 The transport sector should be given priority because it accounts for 60% of total final demand for refined petroleum products. A 15% reduction in the projected 1990 consumption in transport would save

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1/ In the meantime, YPFB has modified the design of the Altiplano pipeline and will therefore have to renegotiate the loan.

2/ Capacity of 55 MMCFD at Cochabamba versus an immediately connectable demand of 16.1 MMCFD, in Cochabamba, Oruro and La Paz.

enough liquid fuels to supply the requirements of the household sector, without having to develop gas distribution pipelines in Bolivia's major cities. Among the immediate measures should be included:

(a) improving traffic flow in urban areas, by introducing and enforcing parking and stopping regulations, staggering work hours to spread commuter rush over a longer period; introducing priority lanes for mass transport;

(b) continuing the import ban on diesel-engine vehicles;

(c) sustaining an effort to rehabilitate the road infrastructure and improve road maintenance to increase the efficiency of transport. At the same time, the mission recommends that a study be made to evaluate the feasibility of replacing part of the asphalt (most of which must be imported) used in road paving by mineral sulphur, to reduce the cost of paving; and

(d) carrying out studies to improve truck capacity utilization (increasing load factors) in interregional freight traffic.

1.26 In the industrial sector, the expected changeover to natural gas in major plants offers an opportunity to survey their energy requirements and to plan the conversion program in a way that the efficiency of energy utilization (gas, liquid fuels and even electricity) is increased to a level consistent with the best current practice. The mission suggests that YPFB create a technical advisory service to promote and assist industries in their conservation projects.

1.27 Energy surveys and audits should immediately be made in about two dozen major industrial plants, including tin smelters, cement, glass, paper, ceramics, sugar plants and the oil refineries. At the same time, it is suggested that the scope for product waste recovery by pollution control equipment be assessed. Once potential savings are identified and quantified, YPFB should provide technical assistance to evaluate and implement projects and credit lines should be opened to those enterprises which have agreed on an conversion-conservation project with YPFB (paras. 4.16-4.29).

Foreign Trade

1.28 Currently, the oil industry has a surplus of gasoline and LPG and confronts an increasing shortage of diesel and fuel oil. This imbalance between refinery yields and the structure of demand cannot be solved through refinery modification. However, in the long term, the substitution by gas will considerably alleviate the problem. 1/

1/ The Bolivian crudes yield on the average 62% of light fractions, 33% of middle distillates and 5% of fuel oil, while the domestic market demands 52% of LPG and gasolines, 38% of kerosene and diesel and 11% of fuel oil.

1.29 In the meantime, YPFB tries to barter its surplus with neighboring countries. Despite high transport costs, which probably cannot be reduced without considerable investment, Bolivia could profitably expand its foreign trade if its industry could use fuel oils with higher sulphur content. The mission recommends that YPFB study the characteristics of the fuel oil burning equipment of its major industrial clients (paras. 4.13-4.14).

B. Electric Power

1.30 In early 1983, the national power company ENDE reassessed its expansion program and modified its 1981 investment plan, to take into account the lower than expected growth in energy demand, the country's present financial constraints and the transfer of the La Paz market to ENDE.

1.31 In the new version of the electric plan, it is estimated that demand for electricity would grow at 5.2% per year during 1982-1985, increasing to 6.5% p.a. in the period 1985-1990. Under these assumptions, ENDE considers that, with the capacity additions currently being executed, energy and peak demand can be supplied until 1986, and that final decisions on further capacity expansion and on the choice of the primary energy source for power generation can be postponed a few years.

1.32 The economic choice between gas-based thermal generating capacity and hydro-power expansion depends on the opportunity cost of natural gas. The mission has estimated (assuming a 12% discount factor) that if the export value of gas in Santa Cruz is above US$3.30/MCF then the least cost solution for future expansion is the development of Bolivia's hydropower potential.

1.33 The mission, therefore, recommends that the hydropower projects be postponed until the negotiations with Brazil have been completed and Bolivia's economic prospects have become clearer. This would also provide the necessary time to resolve the technical issues related to two specific hydropower projects (Icla and Misicuni) and to revise the cost estimates of other projects, including the geothermal alternative. In the meantime, additional capacity requirements can be supplied by the installation of gas turbines or combined cycle.

1.34 Most of the isolated and rural power systems depend on scarce diesel for power generation. ENDE is gradually assuming responsibility for the power supply in these systems, and should consider the possibility of connecting them with the integrated system and/or study the feasibility of installing small hydro plants or other renewable-based generating equipment.

C. Fuelwood and Other Renewable Energy Sources

1.35 Bolivia has considerable forest resources and exports about 90,000 m^3 high quality wood products per year. However, these resources are located mainly in the scarcely populated tropical lowlands. In the Altiplano, there is practically no remaining forest cover and the large rural population relies on shrubs and animal waste to satisfy their energy requirements, with consequent adverse effects on the already highly eroded environment. In the southern tip of Bolivia (Tarija), uncontrolled past deforestation has caused an erosion problem of major proportion. In some of the Altiplano valleys, soils are not suitable for sustained agricultural activities and reforestation could provide the local population a means to increase their agricultural revenue through the sale of timbers, fuelwood and charcoal.

1.36 Total fuelwood consumption is estimated at 2.1 MMton in 1980, of which 42% is in the Altiplano and 29% each in the valleys and the lowlands. In addition some 2,500 tons per year of charcoal are being produced, most of which comes from the Santa Cruz and Chaco regions and is consumed in Bolivia's tin smelters some 1,000 km away. In the Altiplano unconventional energy technologies, such as biogas, windpower and solar energy, are expensive relative to the income of the rural household and require a social and technical environment that can only be brought about through continuous technical support. Furthermore, the conditions of the Altiplano limit considerably their potential to serve as fuel for cooking. The mission therefore recommends that the energy problem of this region be treated as a part of integral rural developmemt programs and energy technologies be adapted taking into account the conditions of each location.

1.37 A national forest program needs to be developed to improve the supply of energy, protect the soils from erosion and to rationalize the exploitation of tropical forests. The mission has identified three specific areas of action.

(a) In the Altiplano, it is suggested that the already existing and successful reforestation projects LOS OMASUYOS/LOS ANDES be expanded to meet the demand for seedlings and technical assistance of the intended local population. Furthermore, assistance is required for agricultural research of multipurpose crops (food and energy) and applied forestry research to identify new trees which would survive in the harsh Altiplano climate. In addition, a site should be identified near ORURO to develop a reforestation program with fast growing fuelwood species in order to guarantee supplies of charcoal at lower cost to the tin smelter of VINTO.

(b) In the Tarija Valley, the current soil recuperation program should be expanded to avoid further loss of agricultural lands. (It is estimated that some 800 Ha of land are being lost per year). It is suggested that small woodlots and strategically located industrial forest plantations be developed to take the pressure off the few remaining wooded areas and allow regeneration. The program has to be complemented by protection from overgrazing and civil construction works.

(c) In Chuquisaca, the regional development corporation has been successful in developing a reforestation and conservation project in an area which has almost been completely deforested. This project promotes planting of small woodlots near the local ceramics industry and, thus, reduces the cost of firewood to these companies, creates immediate employment, provides a cash income for the rural population, and improves soil conservation and water management. Technical and financial assistance to increase the capacity of the nurseries, improve species selection, reforestation techniques and monitoring activities and expand into new rural areas are required.

(d) In the tropical lowlands, technical assistance should be provided to rationalize exploitation of industrial woods and to improve the efficiency of charcoal production. This program should include forest management techniques, harvesting practices, transport, and use of waste wood.

D. Policy Implications

1.38 The considerable investment requirements, the level of energy prices in the internal market and some institutional weaknesses are the main constraints to achieving the sector's objectives. Therefore, the mission recommends some policy changes to overcome these limitations.

Investments

1.39 The minimum energy sector investment requirements for the decade are estimated at US$2,300 million, assuming that the gas export project to Brazil is implemented. The annual capital expenditures would raise from about US$210 million per year during the period 1982-86 to about US$300 million per year for 1986-1990. This would represent approximately 53% and 60%, respectively, of the estimated total public investment budgets for both periods. These shares for energy are extremely large considering the need for stimulating the other sectors of the Bolivian economy and the country's limited borrowing capacity, and indicate that the alternative strategy of increasing private participation in the development of the sector should be considered (paras 7.11-7.13).

1.40 Under the assumption that the pipeline project does not materialize, the minimum investment requirements in energy would decrease to about US$1,000 million, with annual average expenditures of US$82 million during 1982-86 and US$142 million during 1986-1990. This represents 21% and 28%, respectively, of estimated total public capital spending. The difference between the two scenarios is mainly due to the direct cost of developing the gas fields and building the export pipeline and to the switch from gas to hydro for expanding the generating capacity of the electric system.

Energy Pricing

Hydrocarbons

1.41 There are two different pricing problems to be solved in the hydrocarbon sector: the absolute price level and the relative price structure (Chapter 7B).

1.42 On November 6, 1982, the Bolivian Government increased domestic oil product prices by about 200% to an average of about US$16 per composite barrel. Although these prices are still 50% below their opportunity cost the measure is a significant step towards restoring the financial position of the oil corporation (YPFB). The mission recommends that prices be pegged to the dollar and raised gradually and periodically at a higher rate than internal inflation and that the Bolivian Government adopts the objective of setting prices at the opportunity cost level.

1.43 The relative prices of oil products and natural gas must be structured so as to give the right incentives to interfuel substitutions. The price of gas should reflect its opportunity cost or its supply cost. Fuel oil and diesel prices must be increased to the level of gasoline in energy equivalent terms to reflect their scarcity. Simultaneously, the kerosene price and the price of domestic LPG should be increased to avoid their use as substitute fuels in the industrial sector.

1.44 The opportunity cost of natural gas depends on whether or not a pipeline to Brazil is built. Immediately, the price of gas should be doubled to US$2.00/MCF, to cover its production and transport costs. At that level, it would be equivalent to a fuel oil price of US$11.40/bbl and allow an adequate margin for recovering the expenditures in conversion equipment. Once the exports to Brazil take place, the price of gas in Bolivia should be raised to the equivalent of the export net back in Santa Cruz plus transport cost. Under the lowest price assumptions, this value should be in the order of US$2.80-3.65/MCF.

Electric Tariffs

1.45 ENDE is in a very strained financial position. Although the Electricity Code guarantees a 9% rate of return, the corporation achieved only a 6.8% rate of return in 1981. In 1982, the Government authorized a 517% increase in tariffs (54% in February and 300% in November). However, the average bulk tariff (US¢3.7/kWh) is still below the estimated long run marginal cost (US¢5.85/kWh under the hydro-based expansion alternative) and does not permit meeting ENDE's objectives of a 9% rate of return and level of self-financing of 44%. Thus, the mission recommends that tariffs be gradually adjusted upwards by a rate higher than internal inflation with the objective of reaching the level of the long term marginal costs.

1.46 Furthermore, there are considerable differences in the tariffs applied by the regional distribution companies, both in terms of the levels of the energy and demand charges and of their structure. The mission urges the Government to proceed as soon as possible with a national tariff study.

Institutions

1.47 To meet future energy needs, the Ministry of Energy and Hydrocarbons has to fully assume its responsibility for formulating energy policies, coordinating plans and monitoring the execution of projects within the energy corporations. To this end, a strong and capable planning department must be created, adequately staffed and trained. (Chapter 7C)

1.48 To achieve the desirable changes in the pattern of consumption, the support of the Bolivian population must be obtained through a public information campaign, technical assistance, a legal framework and credit lines for conservation project evaluation and implementation.

1.49 In the hydrocarbons sector, the policy regarding private participation in the activities of the sector must be more clearly defined. The general Hydrocarbon Law and/or its regulations should be revised to adjust the contract model to the current features of international contract formulas. It is suggested that attention be given to forms of private sector participation that, while not conferring any title to production, would directly link contractor remuneration to successful increases in petroleum production. It would also be advisable to modify the tax laws and change the taxable income basis from gross to net revenues. These measures would enhance interest in marginal prospects and induce private participation in peripheral activities.

1.50 The loss of professional staff in YPFB, the inadequate delegation of authority and accountability and the lack of coordination between operating and financial objectives are serious problems that hamper the national oil company's performance. The mission recommends that the following measures to strengthen the institution be implemented:

(a) Definition of the specific functions of each managerial and operating unit, with clear formulation of objectives, staff requirements and control systems.

(b) Reform of the salary structure, directly relating salaries of management and technical personnel to the level of responsibility, productivity and to the competitive levels in the private sector in and outside Bolivia.

(c) Outline of a career development program, taking into account YPFB's long term managerial and technical personnel requirements.

(d) Introduction of new and upgrading of already existing administrative and financial control systems and methods, in order to provide management with up-to-date and continuous information on stocks, flow of inputs and outputs, and on financial transactions.

(e) Introduction of modern analytical tools (models) to plan and evaluate investment strategies and to optimize present operations.

(f) Contracting an outside productivity and performance expert, with sufficient authority to induce changes that will result in cost savings.

1.51 In the power sector, the long standing issues with the Bolivian Power Company have apparently been solved by the Government's announced decision to nationalize this private company. The integration of the largest market (La Paz) into the national power company (ENDE), was an additional reason for revising that company's development program. In addition, the Mission recommends that a national tariff study be performed.

1.52 A sustained and orderly effort must be made to improve rural energy supply. The Institute of Rural Electrification does not have the technical and financial capability to execute such a policy. The mission recommends that an alternative institutional arrangement be sought for executing the rural electrification programs.

Technical Assistance

1.53 The main areas in which external assistance is required and not yet provided can be grouped as follows: (a) planning at the global energy level as well as in specific fields of the hydrocarbon, power and forestry sectors (b) demand management including energy surveys and audits; and (c) specific studies. This assistance should emphasize training of local personnel to insure continuity of action. A detailed list is provided in Annex 4.

II. THE ECONOMY AND ENERGY

Background

2.01 Bolivia has a population of 5.7 million and an area of 1.1 million km^2, divided in three regions with distinct economic and trade patterns. About half of the population is located in the Altiplano, (a highland three to four thousand meters high) occupying about one third of the country's area in the west and southwest. The valleys (Yungas) and the tropical lowlands (Llanos) in the east and north account for 49% of the population and 65% of the area.

2.02 Although each region has a good energy resource base, the Altiplano has currently a huge energy deficit. The Altiplano valleys have a substantial hydropotential and the highlands itself have good solar irradiation but these resources have not been fully developed and no hydrocarbon deposits have been found in this region. The rural population suffers from an acute shortage of fuel, because of the almost complete absence of forest cover (depleted since colonial times). The urban population and the energy intensive mining and metallurgical activities depend on liquid fuels (65% of Bolivia's total consumption), which are met by supplies from the lowlands through a well developed pipeline system. Also, the Altiplano region is now being connected with the eastern electric power system based on natural gas. This offers the choice between expanding the generating capacity by developing the Altiplano hydropotential or importing electric power from the eastern lowlands.

2.03 The lowlands have a low population density but experienced remarkable economic growth during the 1970's, largely based on the exploitation of this region's hydrocarbon resources. In addition, they benefit from relatively virgin agricultural lands with high productivity. This region maintains close trade relations with Brazil and Argentina whereas the Altiplano is better connected with the Pacific through Peru and Chile.

2.04 Bolivia is a net exporter of energy. The weight of energy in foreign trade (Table 2.1) has continuously increased over the decade, despite the fact that the exportable oil surplus has ceased to exist and that Bolivia depends now on the willingness of one customer (Argentina) to buy its natural gas.

Table 2.1: Hydrocarbons and the Balance of Payment
(millions of US$)

	1970	1976	1978	1980	1981
Net Hydrocarbon Exports: 1/					
Crude oil	13.2	112.6	42.3	-	-
Petroleum Products	(1.1)	(6.0)	(6.8)	22.6	2.5
Gas	-	59.9	78.5	220.9	326.2
Total	12.1	166.5	114.0	243.5	328.7
Total Exports 2/	206	637	705	1,044	1,015
Total Imports 2/	180	674	912	958	1048
Net Trade Balance	26	(37)	(207)	86	(33)
Share of Hydrocarbons in Foreign Trade:			%		
Hydrocarbons/Total Exports	5.9	26.1	16.2	23.3	32.4
Hydrocarbons/Total Imports	6.7	24.7	12.5	25.4	31.4

1/ Data derived from YPFB printouts.

2/ Central Bank of Bolivia. Exports and imports include non-factor services.

2.05 The isolation of the individual regions and the relatively small population have not permitted the establishment of strong internal links between Bolivia's productive sectors. Thus, economic growth depends heavily on the level of economic activity in the industrialized world. Bolivia's agriculture accounts for about 16% of GDP, provides employment for over 45% of the labor force and contributes 10% to exports. Mining and hydrocarbons account for 11% of GDP and 90% of exports, but employ only 5% of the labor force. Manufacturing contributes only 14% to GDP and 7.5% to employment. The service sector's share is about 60% in GDP and 40% in employment (Annex 1.1).

Recent Economic Developments

2.06 Bolivia is currently going through one of the most difficult phases of its economic history. Since 1979 the country has been facing severe foreign exchange constraints, caused by declining prices for its mineral exports and the increasing cost of foreign debt service. The immediate consequence of the balance of payments disequilibrium and fiscal deficit was a slowdown in GDP growth from 5% per year during 1970-1978, to 2% in 1979, 0.8% in 1980, -0.6% in 1981 and a 7.4% negative growth in 1982. In 1981, the per capita GDP was already 6% lower than in 1978 and urban unemployment has been growing while capacity utilization has continuously declined since 1979.

2.07 The Bolivian government has to make difficult choices to gradually redress the economy. It has opted for a foreign exchange policy that gives priority to the repayment of the foreign debt. This debt equals some two years of export earnings and its service represents in 1982 an estimated 66% of export earnings. To this end, the GOB has curtailed the allocations of foreign exchange, devalued the Bolivian currency 1/, and eliminated subsidies on basic foodstuffs. This strategy has a high cost in terms of foregone output and in social well-being, as already evidenced by the events of 1982.

2.08 Prospects for next few years are dim. The international economic recession has reduced mineral and agricultural prices to an historical low. Even if world economic growth resumes, prices are likely to remain stagnant for some time. Manufacturing exports, that could become competitive as a result of the domestic deflation, start from such a small base that their impact on the foreign trade balance will remain quite small. Adding to these prospects the country's overextended credit position, it becomes clear that the lack of foreign exchange will restrict imports, investment, and therefore growth, unless a new source of foreign earnings is tapped. This is the reason why the long standing project to export natural gas to Brazil has now been revived. If contract negotiations with Brazil are successful, a pipeline could be built in about four years and Bolivia could possibly expect to triple its hydrocarbon export revenue.

2.09 On November 6, 1982, the Government has announced important economic measures. These aim at: (a) introducing some stability in the foreign exchange market by reunifying the two markets prevailing since March 1982 and establishing a single exchange rate of $b200/US$, and (b) by increasing public sector enterprises income and tax receipts. This is especially relevant for the future development of the energy sector. Prices for hydrocarbon products were increased by about 200% and electricity tariffs by 300%. This restores a more adequate level of revenue to finance the crucial investments required to meet projected energy demands.

1/ On February 5, 1982 the peso was devalued from $b25/US$ to $b44/US$. In March 1982 a dual foreign exchange market was established; 40% of all export proceeds were purchased by the Central Bank at the rate of $b44/US$ and the remaining 60% were sold on the free market. In June 1982, the free market exchange rate was $b120/US$, by September it reached the $b300/US$ mark. On November 6, 1982, the two rates were reunified at $b200/US$.

Present Energy Demand Structure

2.10 In 1981, Bolivia consumed internally about 2.8 MMTOE of primary energy and exported 1.9 MMTOE. (Annex 1.14) Of the internal gross consumption, 39% was provided by crude oil and condensates, 15% by natural gas, 11% hydropower and 35% by biomass. (Table 2.2) Of the exports, 98% consisted of natural gas (via the pipeline to Argentina) and the rest of LPG, gasolines and naphthas.

2.11 The per capita energy consumption of 500 kgoe is comparable to that of countries with similar levels of income, but low in relation to other Andean countries (which average 880 kgoe) or the Latin American region (1,010 kgoe) which have a higher level of income. Similarly, there is a large differential between urban and rural energy consumption within Bolivia. On a per capita basis, the rural population uses probably about one-fourth the energy of the urban and then mostly non-commercial fuels. These comparators serve to illustrate the energy implications of economic growth and the need to initiate at an early stage programs to improve the energy supply to Bolivia's rural areas.

Table 2.2: 1981 Bolivia's Energy Market Structure

GROSS SUPPLY			NET DEMAND		
Source	000TOE	%	Sector	000TOE	%
Biomass	987	35			
Hydro	310	11			
Oil	1100	39			
Natural Gas	441	15	Industry 419	20	
TOTAL	2838	100	Mining 64	3	
Intermediate Demand	351	12.4	Transport 660	31	
Statistical Adjustment	342	12.1	Residential/ Commercial	1002	46
Final Consumption	2145		Final Consumption	2145	100

Source: Annex 1.3.

2.12 The intermediate demand for energy in conversion, transport and distribution absorbs about 12.4% of gross supply. The consumption of gas in the export pipeline amounts to about 10% of throughput. Two refineries have been converted to use gas as fuel, but the largest one (Cochabamba) still relies on liquids (mainly gasoline). Electric transmission and distribution losses are estimated at 16% of gross generation. Evidently, the efficiency with which energy is used in the energy sector itself can be improved and the mission recommends that this sector be included in the conservation effort.

2.13 Table 2.2 above also provides an indication of energy consumption by economic sectors. About 31% of total final energy is consumed in transport; 23% in the mining and industrial sectors and 46% can be allocated to residential, commercial and other sectors. It is estimated that 75% of the residential/commercial consumption consists of biomass (fuelwood, shrubs and dung) which is used with a lower efficiency than commercial energy forms, and about 30% of industrial consumption consist of bagasse used in the sugar cane industry.

2.14 About 60% of final market requirements are supplied from commercial energy sources and liquid hydrocarbons provide the bulk of this demand. Although important gaps in information exist, an attempt to allocate this demand by sectors of consumption and type of fuel is made in Table 2.3 below. 1/

Table 2.3: Commercial Energy Consumption, 1981
(MTOE)

Sectors	LPG	Gasoline	Kerosene Jet Fuel	Diesel	Fuel Oil	Total Liquid Hydrocarbons	Gas	Electricity	Total
Industry	8	-	28	34	116	186	54	32	272
Mining	-	-	2	17	9	28	-	37	65
Transport	4	389	99	165	3	660	-	-	660
Residential/ Commercial	140	-	62	-	-	202	-	55	257
Total	152	389	191	216	128	1076	54	124	1254
Shares: %						86	4	10	100
%	14	36	18	20	12	100			

Source: Annex 1.3.

1/ For example, most LPG sales are in 10 kg containers aimed for household. However, there is evidence that industries bought them because they are cheaper or because the equipment to supply or use industrial LPG is insufficient. It also appears that a significant portion of LPG was illegally exported. On the other hand, purchases of diesel oil for power generation in isolated electric networks were allocated to intermediate demand and do not figure in final energy consumption. This statistical treatment enhances the relevance of the transport sector as user of diesel oil.

Trends in energy consumption by energy form

2.15 The trend of commercial energy consumption in Bolivia over the last decade has closely followed the performance of the economy. During the relatively prosperous first half of the decade, from 1970-76, when the economy grew at almost 6% per year, the consumption of commercial energy grew at 10.2% per year (Table 2.4). With the slowdown of the economy in the second portion of the decade, GDP grew on the average at only 3% per year, commercial energy consumption growth also fell, to 5.8% per year. The increase in the commercial energy/GDP elasticity from 1.7 to 2.0 between the two periods is due to the commissioning of energy intensive industries and probably to a decrease in the efficiency with which energy is used, characteristic of periods of low capacity utilization.

Table 2.4: Energy Intensity in the Bolivian Economy

	1970	1976	1978	1979	1981 2/	Annual Growth Rate % 1970-76	76-79	79-81
All Sectors								
Value Added (10^6\$US 1970)	1,031	1,456	1,552	1,584	1,587	5.9	2.9	0.0
Commercial Final Energy Consumption-Total (MTOE 1/)	609	1,079	1,294	1,302	1,303	10.0	6.5	0.8
Liquid Fuels	539	928	1,121	1,141	1,122	9.5	7.1	-0.8
Electricity	66	96	114	121	124	6.4	8.0	8.0
Gas	-	48	47	30	57	-	-	23.3
Energy Intensity (Kgoe/US$)	0.591	0.741	0.834	0.822	0.795			
Energy Intensity at the Margin (tons/million US$)	1.00	1.00	1.31	1.74	1.71			

1/ Total includes other commercial energy forms such as coke and charcoal.

2/ The energy balance for 1981 was developed by Mission using a methodology slightly different from the previous balances prepared by MEH. In ordere to facilitate comparison, adjustments were made in the figures for 1981 given in this table.

Source: Energy Balances - Ministry of Energy and Hydrocarbons 1970-79. Mission estimate 1981.

2.16 The trends in the liquid petroleum consumption are shown in Table 2.5. It is to be noted that since 1978 sales of all oil products excluding LPG have stagnated and were 4% lower in 1981 than in 1978. Diesel oil and aviation fuels' sales have grown on the average by about 15% per year during the decade. Pricing policies have stimulated the use of diesel oil in transport and its use as industrial fuel has further been encouraged because of the progressive deterioration of the quality of fuel oil available in the Bolivian market. The rapid increase of demand for aviation fuels reflects the country's landlocked situation and the poor internal road and railway networks.

Table 2.5: Domestic Petroleum Product Sales 1971-81

	Average Annual Change %	Energy/GDP Elasticity
Total Sales	8.5	2.01
LPG 1/	34.2	8.07
Gasolines	5.8	1.37
Diesel	14.6	3.45
Aviation Fuels	15.1	3.55
Fuel Oil	3.6	0.86

1/ Kerosene sales grew at 4.3% per year between 1971 and 1978. After that year they declined on the average by 15.4%, being substituted by LPG.

Source: Annex 1.16

2.17 About 72% of the urban and 9.1% of the rural population have access to electricity and the average per capita consumption (268.5 kwh in 1981) is low compared to the Latin American average (850 kwh). The historical figures indicate that electricity sales increased from an average of 6.5% p.a. during 1970-76 to 8% p.a. in 1976-1981, and the elasticity with respect to GDP jumped from 1.06 to 2.76. However, this explosion was regional and due to the fast industrial expansion in the Santa Cruz area and to a lesser extent in Cochabamba, and to ENDE's capability to finance new generation facilities to supply this attractive market. Sales in the Oriental (Santa Cruz) System grew at an average of 20% p.a. and in the Central (Cochabamba-Oruro) System at 8.8%, whereas the demand in the rest of the country rose on average by 5.5%/year (Annex 1.29).

ENERGY CONSUMPTION IN THE 1980s

2.18 The long range projection of future energy demand is generally subject to a wide margin of error and this task is made particularly difficult for Bolivia because the energy sector and the economy are undergoing major transitions. In order to provide an analytical basis the mission has opted for the following scenarios for 1990:

(a) Baseline Scenario: this projection is based on global energy consumption/GDP elasticity of 1.2 and a commercial energy consumption/GDP elasticity of 1.7. Under this assumption, final commercial energy demand would be 58%

higher in 1990 than in 1981, and the oil deficit would be equal to 610 MTOE or about 13MBD (Annex 1.4).

(b) Baseline Scenario with Substitution: in order to compensate for the oil deficit, gas would have to substitute for all liquid fuels in the industrial sector and also provide for 32% of the commercial energy requirements of the residential/commercial sectors. This implies a huge investment effort in the construction of gas distribution networks in major industrial cities (Annex 1.5).

(c) Baseline Scenario with Substitution and Conservation: It is reasonable to assume that the efficiency with which energy is used in Bolivia could be increased by at least 15%, and that as a result the commercial energy/GDP elasticity would decrease to 1.2. In this projection, electricity supply was maintained at the level projected in scenario (a), thus implying additional replacement of liquid fuels. Under this scenario, the oil deficit would be reduced to 171 MTOE, equivalent to about 18 MMCFD of natural gas which would be supplied exclusively to the major industrial consumers (Annex 1.6).

(d) Accelerated Growth Scenario with Substitution: In order to assess a more extreme case, the final demand of scenario (a) was increased by the specific industrial projects the Bolivian Government and private enterprise are considering for implementation during this decade. Furthermore, ENDE's projection of power demand (Chapter 5) was introduced. Under these assumptions, the oil gap in final consumption to be covered by natural gas would increase to 750 MTOE or 78 MMCFD (Annex 1.7).

2.19 In all the former projections it has been assumed that the incremental power requirements of the integrated system will be gas generated, those of the isolated networks are diesel fueled. Similarly, most of the refinery fuel is natural gas. These requirements have to be added in order to arrive at primary demand for energy, indicated in Table 2.6.

Table 2.6: Projected Commercial Energy Requirements
(MTOE)

	1981	1991 Baseline	1991 Baseline With Substitution and Conservation	1991 Accelerated Growth With Substitution
Total Primary Requirements	1846	2833	2430	3255
Hydro	310	310	310	310
Oil 1/	1095	1608	980	980
Gas	441	915	1140	1965
Final Domestic Demand	1254	1980	1683	2391
Oil Products	961	1533	932	920
LPG from Gas	115	167	379	459
Natural Gas	54	79	171	750
Electricity	124	201	201	262

1/ Does not include natural gasoline obtained from gas and processed in the refineries. This stream is included in gas.

Projections of Energy Consumption to year 2010

2.20 The relevance of natural gas in the Bolivian economy is likely to increase substantially over time to satisfy domestic energy requirements and to serve as an input into industrial processes, as well as a generator of export earnings.

2.21 The domestic market has a first claim on gas reserves. In the case of Bolivia, gas will substitute for oil deficit which otherwise would have to be imported. The length of time over which domestic gas requirements are computed has a significant impact on the exportable surplus volume, and then on the gas utilization policy. Many countries have fixed this period as a function of their energy options and the lead time estimated for new technologies to economically replace natural gas. For instance, Canada has set aside gas reserves equivalent of 30 years domestic requirements; New Zealand has enacted a conservation policy limiting production to a level which will leave 50% of the Maui field reserves in place in the year 2000, in order to assure supplies to direct consumers of gas through 2030.

2.22 The definition of this period is crucial in the case of Bolivia, because internal gas utilization has only started, and it will take at least 20 years to develop a gas pipeline network to supply the main consuming sectors in regions with highest population densities. To estimate the potential demand for gas during the next three decades, the following assumptions were made: (a) during the 1980's, demand would follow the path described under Scenario C (para 2.18); (b) the Bolivian economy would grow at about 4% p.a. during the following two decades, and the energy/GDP elasticity would be 1.2 in the 1990's and be equal to one thereafter; (c) Bolivia's potential hydro would not be developed during the period and oil and condensate production would decrease by 2% p.a. (d) natural gas would provide all incremental demand of the final consuming sectors as well as supply the energy requirements of the energy sector itself (Table 2.7).

2.23 Under this extreme scenario, natural gas would supply 59% of final energy consumption and 69% of total demand (including intermediate and final uses). It is to be noted that 30% of total gas consumption would be used for power generation. However, Bolivia has a large hydro and geothermal potential that could be developed, releasing natural gas for alternative uses. The final choice must be based on a realistic economic analysis.

Table 2.7: Projection of Long Term Energy Consumption
(in MTOE and %)

	1981		2000		2010	
	MTOE	%	MTOE	%	MTOE	%
Intermediate Demand	448		1579		2511	
Natural Gas	372		1418		2318	
Oil	76		161		193	
Final Consumption	2145	100	4125	100	6106	100
Biomass	891	42	898	22	898	15
Electricity	124	6	374	9	645	11
Liquid Hydrocarbons	1076	50	1118	27	939	15
Natural Gas	54	2	1735	42	3624	59

Source: Annex 1.9.

III. ENERGY RESOURCES

3.01 Bolivia's commercial energy resources are estimated at 1,230 million tons of oil equivalent, which at the present rate of domestic consumption would be sufficient for the next 400 years. However, this relative abundance glosses over potentially severe supply constraints, because of the unequal rate at which resources are currently being exploited. The resource base includes 18,000 MW of feasible hydro potential 1/ (84%), 6.7 trillion cubic feet of recoverable gas reserves 2/ (14% of resources) and 187 million barrels of oil (2%). Furthermore, Bolivia has excellent solar irradiation and a large agricultural potential, which could provide renewable energy. Bolivia also has a geothermal zone, deposits of uranium in quantities not yet defined and indications of coal and lignite. What is needed is a well structured program to develop these resources over time at a minimum cost and with maximum and equitable benefit to the various groups that comprise the Bolivian society.

Hydrocarbons

3.02 The proven recoverable reserves of Bolivia as of July 1, 1982, are estimated to amount to 26 MMB of crude oil, 78 MMB of condensate and 5.0 TCF of gas (Annex 1.10). 3/

3.03 The probable recoverable reserves are estimated to amount to 83 MMB of crude and condensate, and 1.7 TCF of gas. The probable reserves include the fields recently discovered by YPFB (Tacobo, Huayco, and Montecristo), and by Tesoro (Los Suris, Escondido and Taiguati). Furthermore, possible reserves are estimated at 17 MMB of crude oil, 43 MMB of condensate and 1.6 TCF of gas. This estimate only reflects the statistically calculated results expected from the next five years exploratory program.

3.04 The history of exploratory activities shows that 112 structures have been tested and 34 discoveries have been made. More than two-thirds of the resources discovered consist of natural gas and more than 75% of all hydrocarbons are contained in only 7 fields. Annex 1.11 relates exploratory efforts during the last 20 years to the discovery of reserves. It shows that the overall success ratio is high (one out of five exploratory wells is a producer), but that results are declining.

1/ Calculated at the thermal equivalent of 2867 kcal/kWh, over 40 years.

2/ Includes proven and probable reserves.

3/ All reserve estimates were obtained from internal sources of YPFB. The company does not report changes in reserves' levels, due to new discoveries, extension of field limits or increased recovery factor. Proven reserves include Class I and II; probable reserves include Class III as of July 1981, plus estimates of recent exploration results.

While 195 BCFGE 1/ were found per successful well in the 1960's, only 115 BCFGE were discovered in the 1970's. Furthermore, practically no oil fields have been discovered in the 1970's. However, it is important to note that three discoveries in 1978 have found 20% of the total gas reserves. This development is undoubtedly due to better seismic techniques that more clearly outline the actual structure of the Bolivian geology.

3.05 A preliminary geological brief (Annex 2) expressed caution with respect to the complex geological structure of Bolivia, which introduces a large degree of uncertainty in any reserve estimate. However, the brief gives further reasons to believe that in traditional areas (Subandean Basin and a portion of the Chaco-Beni lowlands) additional, but moderate amounts of hydrocarbon resources could be found. YPFB intends to extend exploration to new areas (stratigraphic features in the northern flank of the Subandean), expecting to find larger sized deposits. Based on the present volume of proven and probable gas reserves, the mission recommends careful alloctions of this resource to those projects with the highest returns for Bolivia.

3.06 Most fields contain gas and condensate and therefore an increase in oil reserves follows much the same pattern as the additions to gas reserves. The major exception to this rule is the Boomerang Hills Area, where the gas is dry. The relative proportion of oil to gas reserves contained in the fields permits grouping them into three categories. Their level of remaining reserves is indicated in Table 3.1:

Table 3.1: Remaining Proven Hydrocarbon Reserves 1/

	Liquids %	Gas %
Total Resrves Class I, II and III	187.2 MMB	6696 BCF
Oil Fields	26.9	5.8
Condensate Fields	67.7	54.3
Gas Fields	5.4	39.9
Total	100.0	100.0

1/ YPFB uses three categories of proven oil reserves I, II and III. There is a discussion within YPFB on whether group III should be included in probable reserves as done in this Table. Data to July 1, 1982.

Source: Annexes 1.10, 1.19, 1.20, 1.21.

1/ Billion cubic feet of gas equivalent.

3.07 Oil Fields: About 27% of Bolivia's recoverable liquid reserves are located in these fields. The crudes produced have a density ranging from about 47° to 50° API. 1/ Some already depleted fields contained heavier crudes, such as Bermejo in the South, with 25.3° API. All these fields produce associated natural gas and the gas/oil ratio has increased over time up to 10 MCF/B. These oil fields are generally small in size and are in an advanced state of depletion, with productive capacity declining at a rate of 20% per year. Only two (Camiri and Caranda) originally contained reserves of more than 50 MMB and only two additional fields (Monteagudo and La Pena) contained more than 10 MMB. Only five fields have remaining proven reserves of more than 1 MMB. These are Monteagudo (19 MMB), Caranda (16 MMB), Camiri (10 MMB), La Pena (3.5 MMB) and Cambeiti (1.3 MMB).

3.08 The mission recommends that reservoir engineering studies be undertaken to assess the feasibility of enhanced recovery projects in these fields to compensate for the high rate of decline in production. YPFB, which owns them, has already initiated secondary and tertiary recovery projects in Monteagudo and La Pena. In Monteagudo, a first pilot water flooding project 2/ was successfully implemented in 1980 and a full fledged project was intended to come on stream in 1981, but has been delayed due to lack of financing. 3/ The project is of vital importance, because it still could reverse the field's declining production by 1985-86 from 2.4 MBD in 1982 and 1.2 MBD in 1985 to a peak of 5.2 MBD in 1990. Simultaneously, YPFB has initiated supplementary recovery at La Pena, where it injected into the formation some 30M m^3 of LPG in 1981, obtaining the recovery of an equivalent volume of a 49° API crude oil. The economies of the project seem to be adequate, because YPFB hopes to later recover the injected LPG. The company plans to double LPG reinjection. 4/ This product is produced in Colpa some 30 kms to the north of La Pena.

3.09 Condensate Fields: About 68% of liquid reserves and 54% of proven gas reserves are contained in these fields. They produce condensates with a density ranging from 55 to 70° API. The gas/oil ratio of originally discovered reserves varies between 8 MCF/B (Tita) to more than 40 MCF/B (La Vertiente). This group contains the largest sized deposits. Rio Grande had original recoverable reserves of 78 MMB and 1.4 TCF of gas. Remaining reserves are estimated at 23 MMB and 1.1 TCF of gas. The other large field is Vuelta Grande, which is estimated to contain 44 MMB of condensate and 800 BCF of gas. Other fields with

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1/ Density is indicative of the proportions of light, medium and heavy distillates that can be obtained when processing these crudes. The higher the API number, the lower the yields of heavier products.
2/ Financed by IBRD - under the Petroleum Appraisal Drilling and Recovery Engineering Project 1979.
3/ Included in the proposed IBRD loan for Vuelta Grande.
4/ It has presented a request for financing this project to IDB.

remaining condensate reserves of more than 10 MMB are Porvenir and Montecristo. 1/

3.10 The joint gas-oil production imposes the need for carefully simulating the reservoirs and reevaluating their production programs. Maximum total physical recovery of liquids is achieved over time when gas is reinjected to maintain the reservoirs pressure. In the retrograde gas condensate fields, reinjection is essential and no gas should be produced until such time as the revenue from condensate recovery does not cover reinjection costs. In the case of the Vuelta Grande field, it is estimated that the economic limit for condensate production will be reached 20 years after initial exploitation, and only then will the field be operated as a gas field. Technically, however, it is possible to have a net gas production at an earlier stage. Nitrogen seems to be a good substitute for natural gas as a pressure maintenance agent. Economically, the substitution is feasible if the market value for natural gas is higher than the production cost of nitrogen. This is not the case under present economic conditions.

3.11 Gas Fields: Only in one of the structures of the Boomerang area has oil been found. In general, these fields contain only small amounts of condensates and the gas is usually dry. The gas fields located northwest of Santa Cruz in the Boomerang area are only now being evaluated; 2/ other gas fields might have been discovered in the past but were not evaluated because there was no market for this resource.

3.12 The gas produced in the first two categories of fields generally contains heavier hydrocarbons that can be separated in two streams: (a) natural gasoline (pentanes and heavier) and (b) LPG (propane and butane). On the average, about 4 to 6% of the gaseous volume consists of heavier hydrocarbons that can be extracted. The economic feasibility of LPG recovery from the gas of the Boomerang area will have to be studied.

Exploration

3.13 Bolivia's hydrocarbon resources consist mostly of natural gas. Therefore, wildcat exploration for oil will not be an attractive investment until the market for gas is developed.

3.14 Should the market remain restricted to domestic requirements and exports to Argentina, then efforts should be concentrated only in defining the extensions of the fields already discovered. The prospects of finding new oil fields in conventional structural traps are modest. Therefore, YPFB has an interest in initiating exploration for stratigraphic features where it hopes to find oil, although the exploratory risk is considerably higher and will result in higher

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1/ The latter was discovered in 1976 but has not yet been fully evaluated. It does not figure in some of the production forecasts prepared by YPFB.

2/ IBRD-IDB Engineering Loan.

costs. The mission considers that investments in exploration for stratigraphic features are economic, but should be postponed until the present critical financial constraints ease.

3.15 Should the export project to Brazil materialize, then exploration is necessary and financially feasible. In that case, YPFB, which holds in reserve the areas with the highest hydrocarbon potential, could enter into favorable agreements with private operators, inducing them to risk capital in exploration for stratigraphic traps and in other high risk areas (see Chapter 7).

3.16 In its five year plan 1981-85, YPFB proposed intensifying exploration with investments of some US$320 million during the period. Three-fourth of the program was to be implemented by YPFB, the rest by existing private operators. Under the financial constraints that have developed since 1980, this program must be revised. The mission recommends that in the immediate future YPFB concentrate its efforts in fully evaluating already detected structures and investigate alternative measures that would permit participation of private companies in exploring higher risk prospects.

3.17 The Bolivian Government has invited private participation in exploration several times in the past. At present, only Occidental (US) and Tesoro (US) operate in Bolivia. YPFB has opened new bids in 1981 and intends to assign three areas located in the northwest Subandean Foothill Area, the Madre de Dios portion of the Beni, and to the East of Santa Cruz. These appear to be the only unassigned areas that have the prerequisites for hydrocarbon production. As an enticement, the private companies were offered a share in potential future markets for gas. In future biddings YPFB could consider tying exploration within the reserved known producing area to exploration for stratigraphic traps along the eastern flank of the basin.

Hydro-Potential

3.18 The economically exploitable hydroelectric potential has been estimated at 18,000 MW with an annual generation of 90,000 GWh, enough to cover the growth of electricity demand for another 40 to 50 years. Numerous studies have been made of some of the rivers, and projects with a capacity of some 10,300 MW and generation of 51,000 GWh have been identified (Annex 1.26). At present, installed hydroelectric capacity (287 MW) represents less than 2% of Bolivia's potential.

3.19 Some of these projects are of very large dimensions and far removed from major demand centers. Their development cannot be envisaged at present. Some others imply joint development with neighboring states and are being studied under an OAS regional effort. Another group of projects serves multiple purposes (electricity, irrigation, drinking water), and therefore each region takes active interest in the decision making process. This is the case of Misicuni in Cochabamba, Icla in Sucre and Rositas in Santa Cruz. Restraint should be exerted by the central government to avoid regional pressures that lead to less than optimum investment decisions. The projects included in ENDE's 1981 expansion program are indicated in Table 3.2. 1/

Table 3.2: Hydropower Projects: ENDE's Proposed Expansion Program 1981-91

Project	Firm Capacity	Annual Generation (GWh)	Status and Comments
1. San Jacinto	7	21	Construction contracted in December, 1981.
2. Sakahuaya	72	362	Final design and bidding documents ready.
3. Huaji	26	180	(Feasibility study in (progress.
4. Pachalaca	14		(Generation for the La Paz (market.
5. Icla	90	365	Engineering design in progress. Multi-purpose project.
6. Misicuni	104	460	Feasibility studies completed. Multi-purpose project.
7. Palillada	110	632	Feasibility studies in progress.
8. San Jose	150	840	Only preliminary studies available.

3.20 The evaluation of the expansion program has raised several questions: (a) what is the opportunity cost of capital at which relevant comparison between hydro and gas-based thermal power projects should be made? (b) what is the future economic price for natural gas? and (c) are quoted investment costs reliable and do they reflect realistic appraisals? These questions are discussed in Chapter 5.

1/ In February 1983, ENDE reassessed this expansion program; in the new plan only single purpose hydroelectric projects are included (Huaji, San Jose and Sakahuaya).

Geothermal Energy

3.21 Bolivia has favorable prospects for developing its geothermal potential, which would make it possible to install at least 350 MW 1/ of electric generation. The most promising field "Sol de Manana" has been identified in the area of Laguna Colorada. One well drilled indicated the existence of high enthalpy conditions (150^{o}C at 127 meters depth) but did not provide sufficient information on the deep hydrogeologic conditions of the field. Further geological and geophysical investigation is needed before an exploratory drilling program can be envisaged. A recent pre-feasibility study 2/ for this field, concludes that a 30 MW power plant could be installed at a cost of US$2,000/kW in 1980 dollars (US$50 million for the development of the field and the power plant and US$10 million for a 200 kms long transmission line to Atocha.) The project will have to be further studied taking into account its remote location with respect to the power markets, and compared with hydropower alternatives.

Coal

3.22 Although the coal and lignite deposits found in Bolivia do not appear industrially exploitable at present, the Geological Institute should evaluate more fully their size and characteristics. Consideration should be given to small scale exploitation, to serve as household fuel for the Altiplano rural population.

3.23 An antracite type of coal deposit exists near Copacabana on the Lake Titicaca. Reserves of about 200 thousand tons of coal have been established with an ash content of 35-50%, sulphur 0.38-13%, and volatile materials 14%. Less known indications of coal exist in the department of Cochabamba (Apillapampa and Apopaya). Lignite appears in Cochabamba, Tarija and Chuquisaca. Finally, some peat deposits have been spotted in the Altiplano (Ulla-Ulla and near La Paz).

Renewable Resources

Forestry Reserves:

3.24 Bolivia has large forestry reserves and is a considerable exporter of high quality wood products. However, these resources are located mainly in the scarcely populated tropical lowlands. In the Altiplano, where 50% of the population is located, the availability of energy is very low due to the climatic conditions and the removal of forest cover since colonial times for fuelwood and for the production of pit-props (mine timbers) and for the smelting of ore (silver, tin, gold). In the Altiplano plateaus (about 3,700 meters of elevation), oxygen tension is 40% below that at sea level, temperatures are low and

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1/ "Evaluacion y Aprovechamiento de Recursos Energeticos en Bolivia," UNDP, 1979.
2/ "Proyecto de Desarrollo Geotermico del Area de Laguna Colorada", Electroconsult, Italia. March 1982.

precipitation is seasonally limited. Changes between day and night temperatures are in the order of 17^{o}C and night frosts are frequent. The combination of seasonal dryness and low and rapidly changing temperatures retards the decomposition of organic matter. This slows nutrient cycling and the formation of soils. Furthermore, poor soil composition and atmospheric conditions, which enhance water runoff and evaporation, increase the general dryness of the area. As a result, growth of plants is slow and confined to grasses and herbs and occasional pockets of low trees. Another region in which uncontrolled deforestation has caused an erosion problem of severe proportions is Tarija in the south-west of Bolivia.

3.25 By contrast, the northeastern tropical lowlands of Bolivia are heavily forested and thinly populated. Forest removals are accelerating for industrial purposes (wood is a major export product) and for agricultural colonization, especially in the Santa Cruz region. At present, there is little control on the rate at which extraction takes place.

3.26 Despite these difficult conditions, reforestation is a financially, economically and technically viable activity as has been shown by a number of successful programs. These, however, must be significantly expanded and new ones begun, if adequate supplies of fuelwood, charcoal and other forest products are to be provided, and if erosion control and agricultural production are to be improved. There are three particularly important programs: Los Omasuyos/Los Andes project in the Altiplano, PERTT in Tarija and CORDECH's project in Chuquisaca. The mission strongly recommends that the experience of these projects be evaluated and that the program be substantially expanded (para 6.03-6.13).

<u>Solar Energy</u>

3.27 In principle, solar radiation in Bolivia is suitable for thermal and photovoltaic applications. Global radiation values are estimated between 350 and 750 cal/cm2/day. The highest values are reported for the Altiplano region (Annex 1.39).

3.28 Only limited efforts have been made to disseminate solar technologies in Bolivia. A few private companies have attempted to build solar water heating systems for households in urban areas. Another company is applying passive solar energy to space heating in a low-cost housing project in La Paz. The Institute of Physical Research, in a joint rural development program with the World Bank, has constructed greenhouses in the Altiplano (Ulla-Ulla project).

3.29 In the Altiplano, solar greenhouses are very cost effective. The experience has shown that vegetables and other cash crops (flowers) can successfully be grown, improving the livelihood of the local rural population. It is recommended that the rural extension agencies be endowed with the necessary technical and financial resources to disseminate this technology and to provide adequate follow-up assistance.

3.30 Private entrepreneurs have introduced solar water heating systems in Bolivia since 1980 and a number of units have been installed in single-family houses in La Paz, Cochabamba and Santa Cruz. However, the penetration rate has been slow due to the low price of petroleum products and electricity rates in the Bolivian market and because of the local equipment manufacturers' lack of technical expertise.

3.31 It can be estimated that the installation of solar water heaters in 15,000 residential and commercial buildings could reduce the expansion requirements of the integrated power system by some 30 MW. 1/ Assuming that the installed cost of these systems ranges between US$200-300/kW and that hydropower has a development cost of US$2,000/kW, the net capital savings exceed US$50 million. It is therefore recommended that the Ministry of Energy and Hydrocarbons and ENDE undertake a study to determine what set of policies would be required to promote this option. First of all, technical assistance should be obtained to insure good quality equipment and installation. Furthermore, institutional arrangements to alleviate the first cost barrier of installing the solar water heaters will have to be investigated. The power companies (preferably ENDE) could consider financing the installation and supervise the maintenance of these systems, recovering capital and operating charges through the regular electric bills over a suitably extended period. ENDE would benefit from improved load factors and demand management, and cheaper capacity expansion.

Solar Ponds 2/

3.32 The Government requested comments on the option of generating electricity from Bolivia's largest salt lake, Solar de Uyuni, located approximately 400 kms south of La Paz. There were no data available on the lake's characteristics. However, the mission was informed that the lake is very shallow, with depths not exceeding 50 cms (1.6 ft) and has an area of about 17,000 km^2. Thus, it has a theoretical energy potential of 85 GW.

1/ Solar water heaters can displace up to 3-4 kW of capacity demand per urban high income household for 200-300 kW (electric) installed, depending on the coincidence of water heating demand with power system peak demand (commonly 50-70% coincidence).

2/ Salt ponds collect and store solar energy. Normally, salinity gradient salt ponds are characterized by a surface convective zone, and a gradient zone that serves as a transparent insulator for a lower convective zone where solar radiation is collected and stored as heat. A heat exchanger is required to extract this heat. As salt is added to create a greater salt concentration on the bottom than on the surface to restrict convection, the bottom temperature is much greater than the surface water. Optimum performance requires keeping the surface zone thin and maintaining a thickness of more than one meter in the gradient zone.

3.33 Solar ponds should be considered as a long term alternative for power generation. However, the technology has not been completely proven and only one industrial sized pond (5 MW) is currently being built in Israel at a cost of US$20 million. Other projects are being considered in Cyprus and Tunisia. The mission therefore recommends a preliminary study to obtain data on which to evaluate the real potential, on items such as the salinity level in the lake, evaporation rates, subsoil structure, underground water movement, prevailing wind speeds, etc. Bolivia should also keep abreast with the developments of solar ponds in the world. This would allow Bolivia to incorporate this source in its long term power strategy, and compare it with the hydropower and geothermal options.

Wind Energy

3.34 The available data on mean annual wind speeds for various regions of Bolivia (Annex 1.38) indicates low to medium wind regimes suitable only for water pumping.

3.35 In 1981, a Savonius rotor windmill was built in the Altiplano to test the feasibility of using the rotor in conjunction with a manual water pumping system. The lack of reliability of the Savonius rotor performance, even after 20 years of piecemeal experimentation in several developing countries, hardly justifies the continuation of this research line in Bolivia. It is suggested that in future water pumping projects the design of the more conventional multi-bladed windmills and their more recent variants should be used.

Agricultural Waste Products

3.36 The dispersion of agricultural activity and the cost of collecting vegetal and animal waste is a major obstacle for the use of this biomass as an energy source. Major crops in Bolivia are sugar cane, corn, wheat, rice, potatoes, cassava, cotton, soybeans, coffee, etc. A conservative estimate of the energy value contained in the residues of Bolvia's 1980 agricultural production indicates that an equivalent of 10 MB/D of oil is potentially available from this source. Only a small fraction of this potential is being used as boiler fuel in the sugar industry and as cooking fuel by the rural population of the Altiplano. It appears that, in general, residues are plowed under in Bolivia.

3.37 Given the site specific nature of agricultural residues, further research is necessary to identify localities where supply and demand can be matched and economic projects developed. In this regard, it is suggested that the US AID 1/ initiative to develop and apply a survey and planning methodology for assessing rural energy needs and village level energy resources be further pursued.

1/ USAID - 1980: A Rural Energy Survey and Planning Methodology for Bolivia", prepared by Practical Concepts Incorporated.

3.38 Bolivia's sugarcane productions and mills are located in the Departments of Tarija and Santa Cruz. At present bagasse does not satisfy the mills joint sugar and alcohol production energy needs, and supplemental natural gas, oil and firewood are used (Annexes 1.40-1.41). The analysis of the theoretical energy balance for the sugar cane sector shows that energy is being used at about 41% efficiency (Table 3.3).

Table 3.3: Sugar Industry - Energy Balance - 1980

		Total Energy 10^9Btu
Requirements		
Sugar Cane Processing	2,579,506 tons x 1.38×10^6 Btu/ton 1/	= 3560
Alcohol Production	25,854,000 lts. x 11.22 Btu/lt. 2/	= 0.3
	Total Requirements:	= 3560.3
Energy Used		
Bagasse	850,000 tons x 8.8×10^6 Btu/ton 3/	= 7480.0
Natural Gas	576.7×10^6CFx1045 Btu/CF	= 602.7
Oil (Diesel)	8650 tons x 44×10^6 Btu/ton	= 380.6
Fuelwood	9973 tons x 13.9×10^6 Btu/ton	= 138 6
	Total Energy Used	= 8601.9
	Difference	= 5041.6
	Efficiency of Use	= 41%

1/ World Bank Report No. 3510-MAS, Mauritius: Issues and Options in the Energy Sector, P. 44. Theoretical energy requirements is 1.38×10^6 Btu/ton of sugar cane.

2/ Alcohol from molasses has an energy requirement of 0.56 kcal/kcal of ethanol. Ethanol's calorific value is 5.048 kcal/ltr.

3/ This energy potential is calculated using a very conservative heating value of 8,800 Btu per kg. of bagasse with 50% moisture.

3.39 The mission recommends that a study be made to assess the economic implications of achieving a higher efficiency in the use of bagasse and other sugar cane residues. In a well managed sugar mill, a net bagasse surplus of about 15 to 75 kg (dry weight) 1/ per tonne of cane should be available for alternative uses, depending on the level of

1/ According to "Briquetting surplus sugarcane bagasse to a material suitable for export as a pulp and paper feedstock" published by the Division of Chemical Technology (Technical Paper No. 11), Commonwealth Scientific and Industrial Research Organization, Australia 1982.

technology applied and percentage of bagasse dry weight (fibre) per tonne of cane fresh weight. The latter depends on seasonal as well as species factors. Furthermore, in harvesting sugarcane the following values of residues 1/ are generally left on the field. It has been proven that in leaving these residues on the land does not increase the fertility of the soil. Therefore, this material, which is equivalent to almost eight times the bagasse surplus, could be used for energy purposes.

	Sugarcane Residues Weight per tonne of cane (kg)	
	Fresh Weight	Oven-dry
Hash	90	72
Top and Green Leaves	170	51
TOTAL	260	123

It is recommended that each individual sugar mill be studied in Bolivia, to assess ways on how to improve their energy efficiency and the highest value use to which surplus bagasse and residues should be allocated. These alternative uses include: (a) power generation for the national grid; (b) energy for alcohol production; (c) pelletization and use as boiler fuel in other industries; (d) briquetting for use as household cooking fuel or as industrial fuel; (e) as input into a paper mill.

3.40 The above indicates that there is no justification to build gas pipelines to supply the energy needs of sugar cane mills. These plants should be in a position to satisfy current energy requirements as well as sustain increased alcohol production mainly using bagasse. This recommendation is in particular applicable to the projected gas pipeline in the Department of Tarija, which should not be built until the energy efficiency study of the two Bermejo sugar mills is completed.

Recommendations

3.41 (a) The activities in the hydrocarbon subsector depend on the decision regarding gas exports to Brazil. In the event that this project is not implemented, YPFB should concentrate efforts on maintaining the level of liquid hydrocarbon production. This implies executing the Vuelta Grande, Monteagudo and La Pena projects, defining the extension of already known oil and gas condensate fields and evaluating further secondary and tertiary recovery projects. If the gas export project materializes, then a

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1/ According to: "The Potential for Liquid Fuels from Agriculture and Forestry in Australia" published by Commonwealth Scientific and Industrial Research Organization, Australia, 1979.

considerable exploratory effort is necessary to define ultimate gas resources. In this case, private participation in the sector's activities should be encouraged.

(b) In spite of Bolivia's considerable hydro potential, investment decisions in hydropower development should be delayed until the gas export project has been decided upon and until the technical questions relating to the Icla and Misicuni projects have been clarified.

(c) Further geological and geophysical investigation is needed to evaluate the economic feasibility of the geothermal project of the field "Sol de Manana". As soon as Bolivia's financial constraints ease, this energy source should be further evaluated. In the longer term, solar ponds built in the Uyuni salar lake could also provide an alternative for power generation.

(d) The use of bagasse and of other sugarcane residues must be studied. In all sugar mills there is a potential to enhance energy efficiency and to make available a surplus of organic material for (a) power geneneration for the national electric system; (b) energy for alcohol production; (c) pelletization and use as boiler fuel in other industries; (d) briquetting for use as household cooking fuel; (e) as input into a paper mill.

(e) Coal deposits should be evaluated as to their small scale exploitation to serve as household fuel for the Altiplano rural population.

(f) The dissemination of solar greenhouses in the Altiplano and of solar water heaters in urban areas should be enhanced. Technical and financial assistance to these projects should be sought for by the Bolivian Government.

(g) The US Aid project to study rural energy needs and village level resources should be pursued. The results would enable designing projects in reforestation, agricultural waste recycling, windpower, small scale hydro and other renewable energy sources.

IV. THE OIL DEFICIT & DEMAND MANAGEMENT

4.01 The purpose of this chapter is to determine the nature and the magnitude of Bolivia's impending oil deficit and to evaluate alternative strategies to maintain an adequate energy supply to the modern sector of the Bolivian economy. The first section outlines the assumptions on which the oil production forecast to 1990 were made and compares these to projected demand for oil products. The second part examines the extent to which interfuel substitutions and conservation are feasible, considering the sectoral and regional limitations. The third portion of this chapter discusses the various gas pipeline projects being considered for making gas available to the major energy consuming regions of Bolivia.

A. OIL SUPPLY - DEMAND BALANCE

Liquid Hydrocarbon Production Forecast

4.02 The supply of liquid hydrocarbons (including LPG) depends on the implementation of specific projects. In 1981, it was hoped that the full development of Porvenir, 1/ the enhanced recovery of La Pena, 2/ and Monteagudo, 3/ and especially the development of the retrograde gas condensate field of Vuelta Grande 3/ were going to stabilize crude and condensate production during the first half of the decade and allow the necessary time to evaluate further the resource potential and the feasibility of exploiting the gas fields of the Boomerang area. In addition, YPFB planned to increase LPG production from gas fields from 3 MBD in 1981 to 12 MBD in 1986, mainly by increasing the amount of gas supplied to the existing plant in Rio Grande and by building two new plants in Vuelta Grande and Porvenir. Under these assumptions, total liquid hydrocarbon production would have increased from 27 MBD in 1981 to 40 MBD 4/ in 1986 (Annex 1.12). The projected decline thereafter indicated that the effect of current projects had been compensated by the natural high decline in the productivity of Bolivia fields. There is still a group of fields where secondary recovery could bring forward a significant amount of production.

4.03 The financial resources available to YPFB have been considerably less than postulated in the development plan. The most important project--Vuelta Grande--has not been initiated; the Monteagudo recovery project is being implemented but has not yet been completed. The existing gas plant at Rio Grande is working below capacity and YPFB has considered the possibility of dismantling part of this plant's equipment and use it for Vuelta Grande.

1/ By Occidental Petroleum.
2/ By YPFB, loan from IDB requested.
3/ By YPFB, to be financed through an IBRD loan.
4/ Includes 2.1 MBD from Boomerang area.

4.04 It has therefore been necessary to modify the production forecast, assuming that the pending projects will be reactivated by mid-1983. In 1982 and 1983 the full impact of the Porvenir field development should be felt and give Bolivia an exportable surplus until 1984.

Table 4.1: Projection - Oil and Condensate Production
(MBD)

	YPFB's 1981 Estimates			Mission Revision	
	1981	1985	1990	1985	1990
Oil Fields	6.8	5.7	5.5	4.9	7.5
Condensate Fields	15.2	19.4	10.7	12.4	10.4
Gas Fields	-	-	2.2	-	2.2
Total	22.0	25.1	18.4	17.3	20.1

Source: Annexes 1.12 and 1.13. The difference between these estimates is due to an estimated delay of two years in project implementation.

4.05 The major sources of current gas production are condensate fields. Although their net gas production cannot be increased beyond a certain level in the short run without impairing the recovery of liquids 1/ this volume will increase over time as condensate reserves become depleted and will be sufficient to satisfy domestic gas requirements and the export commitments to Argentina. Therefore, investments in the development of the gas fields in the Boomerang area are justified only in the case of the gas pipeline agreement with Brazil.

Table 4.2 Gas Production Forecast

	Natural Gas (MMCFD)		
	1981	1985	1990
Oil Fields	8.5	28.0	24.0
Condensate Fields	240.0	285.0	294.0
Gas Fields	-	-	330.0
Total	249.0	313.0	648.0

Source: Annexes 1.19, 1.20, 1.21.

1/ At present, this level of flexibility is estimated at around 25 MMCFD or 5% of current production which is approximately the amount of gas being flared or lost in these fields. (Annex 1.22).

4.06 The future of LPG depends on the construction of extraction facilities and of the pipeline system that will provide the gas stream to these plants. As shown on Table 4.3, present capacity utilization is low, due to the declining availability of natural gas to existing plants. The two largest projects--Vuelta Grande and Porvenir--are located relatively close to each other, and it would be advisable to assess whether it is not more economic to build only one of these plants and connect both fields with gas with pipelines.

Table 4.3: LPG Extraction Capacity and Use
(tons/day)

	1981	1985	1990
Rio Grande 1/	450	450	450
Colpa 2/	20	35	35
Camiri 1/	16	40	40
Vuelta Grande 2/ 3/	-	-	356
Porvenir 2/	-	225	225
Altiplano Pipeline 1/	-	-	23
Total (tons/day)	485	750	1,129
Total (barrels/day)	5,546	8,576	12,910
Production (barrels/day)	3,044	5,975	10,040
Capacity Utilization (%)	55	70	78

1/ Information from YPFB's development program.

2/ Information from YPFB's production forecast.

3/ Vuelta Grande is projected to be commissioned by 1986.

4.07 The gas of the Subandean and Chaco region has on the average a propane and butane content of about 4-6% mol. This means that, theoretically, for each 100 MMCFD 2.8-4.3 MBD of LPG can be extracted. Thus, YPFB's projection to produce some 12 MBD of LPG from the condensate fields represents probably 100% of maximum potential with a gas production of 294 MMCFD by 1990. On the mission's revised production schedule it has been assumed that only 10 MBD or 80% of the potential LPG extraction will be available by 1990. 1/ The gas in the Boomerang area is much drier. The analysis will show whether the gas contains an economically recoverable liquid fraction. Total recoverable reserves of LPG have not been determined. Assuming that 4% of condensate gas reserves (3.1 TCF) consists of heavier hydrocarbons (C_3 and C_4), it can

1/ The baseline projection of the energy balance is made assuming a 10 MBD LPG production in 1990. Under the accelerated growth scenario, a LPG production of 12 MBD was assumed.

be estimated that the resource base is in the order of 88 x 10^6 barrels or equal to 24 years production at a rate of 10 MBD.

4.08 To achieve the potential maximum production at a minimum cost, the mission urges YPFB to proceed with a detailed engineering study for each field. This study will provide the necessary input for an optimization model required to program the orderly development of the fields, schedule their production ratios, plan the gas pipeline systems and locate the new LPG extraction facilities.

Projected Oil Balance

4.09 The comparison between the mission's production forecasts and the demand projections (Table 4.4) shows that in the short term the industry should have a comfortable surplus. The deficit foreseen for 1985 is due to a delay in the projects and can be bridged by carefully managing existing productive capacity. The situation however reverts to a continuous deficit at the end of the decade. The deficit will have to be supplied through substitution and demand management.

Table 4.4: Liquid Hydrocarbon Balance - 1981-1985
(MBD)

	1981	1982	1983	1984	1985
Production 1/	27.2	30.5	29.9	28.9	25.4
Demand 2/	26.4	25.4	25.4	25.4	26.0
Exportable Surplus	0.8	5.1	4.5	3.3	(0.6)

1/ Revised Forecast scenario.

2/ Baseline scenario projection, includes 2.4 MBD as intermediate demand.

4.10 The balance for the period 1986-1990 can be projected as indicated in Table 4.5, assuming the baseline scenario with conservation and the full implementation of all programmed oil and LPG projects.

Table 4.5: Liquid Hydrocarbon Balance - 1986-1990
(MBD)

	1986	1987	1988	1989	1990
Liquid Production 1/	33.5	36.5	35.2	34.7	34.2
Demand 2/	28.3	30.7	33.4	36.3	39.4
Surplus (Deficit)	5.2	5.8	1.8	(1.6)	(5.2)

1/ Crude, condensates and natural gasoline.

2/ Baseline scenario with conservation, includes intermediate demand.

Qualitative Balance:

4.11 Bolivia is faced with a severe imbalance between the type of petroleum product demanded by the market and the products that can be refined from domestic crude. Bolivian crude and condensates are unusually light and yield only 15% diesel oil and 5% fuel oil, but about 56% of gasolines and naphthas. On the other hand, 34% of demand consists of diesel and fuel oil. The growth in the consumption of these fuels was encouraged by the pricing policies of the Government, which followed the international price structure and did not consider the characteristics of the Bolivian crude supply. The imbalance will deteriorate in the future, with increased share of condensates in crude input. Currently, to balance market requirements with refinery yields, YPFB has rationed the use of fuel oil, diluted diesel and fuel oil with gasoline, (35% in diesel and up to 95% in fuel oil), exchanged small quantities of products with neighboring countries, and promoted the use of LPG and natural gas, which are in relatively abundant supply.

Table 4.6: Qualitative Imbalance 1981-1990

		Refinery Yields		Consumption			Surplus/(Deficit)	
		1981	1990	1981		1990	1981	1990
	%	MBD	MBD 4/	MBD	%	MBD 3/	MBD	MBD
Gasolines	56	13.6	12.4	8.3	35	13.4	5.3	(1.0)
Kerosene	10	2.4	2.2	1.8	8	2.6	0.6	(0.4)
Jet Fuel	8	1.9	1.8	1.6	7	2.9	0.3	(1.1)
Diesel Oil	15	3.6	3.3	5.4	23	7.9	(1.8)	(4.6)
Fuel Oil	1	0.2	0.2	2.7	11	3.7	(1.5)	(3.5)
Reduced Crude 1/	4	1.0	-	-	-			
LPG	6	1.5	2.3	4.1	17	6.3	(2.6) 2/	(4.0) 2/
Total	100	24.2	22.2	23.9	100	36.8	0.3	(14.6)

1/ This is a feedstock for the lube plant. Part (82%) of the stream is recycled to the fuel oil pool, once paraffins have been extracted.

2/ LPG from natural gas more than covered this deficit in 1981.

3/ Consumption projected under baseline scenario, assuming no substitution.

4/ Includes natural gasoline.

LPG Supply-Demand Balance

4.12 The availability of LPG is crucial in the transition period of the Bolivian economy, because it can substitute for practically all uses of petroleum products in areas in which the energy demand density is insufficient to justify the construction of gas pipelines. Assuming an availability of 10 MBD of LPG from gas plants and 1.3 MBD from refineries in 1990, LPG would supply 53% of household commercial energy requirements, 32% of industrial needs and 20% of road transport fuels. 1/ A shortfall in LPG supply would imply increased investment in the gas distribution network, or accelerated and higher cost extraction of petroleum or imports of liquid fuels. Currently, considerable amounts of propane, butane and natural gasoline are exported in the gas stream to Argentina, in part because some of the gas is being produced where there is no LPG extraction facility. It is recommended that special consideration be given to the domestic requirements of LPG in the gas planning study proposed in this report.

1/ Under the baseline scenario with a 15% conservation effort. Annex 1.6.

Short Term Options to Improve the Qualitative Balance

4.13 Bolivia currently trades LPG and naphtha for diesel and fuel oil with neighboring countries to improve the domestic product balance. The large scale use of this option is constrained by the lack of import pipelines and the fact that domestic refineries as well as the other industrial equipment were apparently designed to handle low sulphur crude oil and products.

4.14 Annex 1.18 shows that trade with the Caribbean exchanging light products for heavy fuel oil would only be justified if the price differential between gasoline and fuel oil is US$13/bbl in that market, amount which is equal to the sum of export and import transport costs; assuming an exchange trade with Ecuador, the necessary price differential is about US$10/bbl. Under present market conditions, such a differential could well be negotiated if Bolivia could purchase high sulphur products or crude and import them in large quantities. It is, however, first necessary to investigate whether the sulphur problem would cause damage to existing installations. The second constraint is more difficult to solve. Current imports are made via railroads; exports in a certain volume can be pumped through the existing and unused pipeline to Arica (Chile). The mission recommends that YPFB investigate alternative routes to reduce transport costs. A more economic access to the foreign trade alternative would facilitate better management of future oil production and avoid incurring heavy substitution costs.

B. DEMAND MANAGEMENT:

Conservation and Substitution Potential

4.15 The Bolivian oil industry will confront increasing difficulties in maintaining constant levels of liquid hydrocarbon production. By the end of the decade, incremental demand cannot be supplied unless major efforts have been made to reduce waste in energy use and a coordinated policy has been implemented to induce a shift of demand towards those energy forms which are in more ample supply. In the medium term, direct use of natural gas appears to be the most economic alternative for substitution. In the longer term, economic trade-offs of substitution between natural gas, electricity and other liquid fuels that can be produced from natural gas, have to be evaluated. In the following, the conservation and substitution potential in each economic sector are discussed.

(i) Industry

4.16 This sector offers the opportunity of achieving significant changes in the pattern of energy consumption with relatively small technical and financial resources. Energy use is heavily concentrated. A dozen major plants account for almost half of industry's petroleum consumption. Six major customers consume 15% of total electricity sales. One large smelter consumes virtually all of the charcoal. The industry's consumption of LPG, kerosene, diesel and fuel oil was about

260 MTOE in 1981. (Annex 1.23) This amount if totally substituted by natural gas would be equivalent to 27 MMCFD. The projection of this sector's requirements to 1990 under the baseline scenario would increase the maximum substitutable market to 381 MTOE or 40.0 MMCFD.

4.17 A detailed survey of the industrial fuel market performed by GDC 1/ recently concluded that, at current prices and from the point of view of individual consumers, there are no technical or economic impediments to substituting natural gas for liquid fuels in the industrial market. 2/ The report did not analyze the economic and financial feasibility of building the pipeline network to supply the market.

4.18 Furthermore, the mission's preliminary survey of eight large industrial plants (of which five were in the public sector) suggest that the efficiency of fuel use--primarily petroleum products but to a limited extent electricity as well--could be significantly improved. A 15% saving could have reduced liquid oil consumption in 1981 by as much as 30 MTOE (or 650 BD) and power requirements by 100 Gwh.

4.19 The metallurgical industry is composed of one large tin smelter (ENAF at Vinto) in operation since 1970 and five other large projects in varying stages of implementation. The Vinto smelter consumes about 36% of the fuel oil sold in Bolivia, and virtually all of the charcoal, which is used as a reducing agent. The capacity of the other projects and their associated energy consumption is listed in Table 4.7.

4.20 All metallurgical plants under construction or planned confront difficulties, because (a) there is a question on whether sufficient ore will be available to operate these plants at an acceptable utilization factor; (b) the economics of La Palca are being questioned on the ground of the overrun in investments and the efficiency of the process technology; (c) the plant has a serious air pollution problem. As a result of these problems, it is probable that the other two planned projects will have a considerable delay in their implementation. YPFB is committed to supply the energy requirements of Vinto and La Palca with natural gas by 1983, or supply these plants with fuel oil at the energy price equal to natural gas. This contract is the prime reason for the accelerated expansion of the Monteagudo-Sucre pipeline. It is recommended that the economic feasibility of these projects be revised before YPFB goes ahead with the investments in pipelines to supply the energy requirements of these plants. Their economic profitability should not be artificially increased through an implicit subsidy of natural gas, by pricing it below its opportunity cost.

1/ Internal Demand for Natural Gas and LPG in Bolivia, by GDC, Inc., Draft of April 1982.

2/ There are a few instances where interchangeability is not complete; for instance metallurgical requirements for specific fuel or for extremely high temperatures.

Table 4.7: Energy Consumption at Major Metallurgical Projects

Plant	Status	Owner	Location Department	Metal	Input Capacity (MTY)	Energy Consumption at Capacity (MTOE)
Vinto	In Operation	ENAF	Oruro	Tin and Antimony	90 concentrate	71
La Palca	Start-up	COMIBOL	Potosi	Tin	140 (ore)	26
Karachipampa	Planned	ENAF	Potosi	Lead and Silver	53 (ore)	16
Machacamarca	Planned	COMIBOL	Oruro	Tin	?	20
Sponge Iron	Envisaged	SIDERSA	Santa Cruz	Iron	?	18
Ore Processing	Envisaged	SIDERSA	Mutun	Iron	?	6

4.21 The mission recommends that an energy survey and audit be performed in Vinto, to assist management in the conversion to natural gas and to achieve at the same time improvement in the plant's efficiency. It is also suggested that the scope for product waste recovery by pollution control equipment be assessed.

4.22 The manufacturing sector is comprised of some eight energy-intensive cement, glass and ceramic plants; of about a dozen of medium-sized textile, food-processing and beverage industries; and a large number of small scale and widely dispersed enterprises.

4.23 The industries in the first two groups were mostly established in the 1970s with modern technology. However, the energy efficiency of these plants has suffered because of the low quality of fuel oil available in recent years, the uncertainty related to the timing and extent of the Government-mandated changeover, first to LPG and then to natural gas, the economic crisis which has hampered and delayed industry's efforts to import essential spare parts and has affected maintenance practices, and finally, the lack of incentive on the part of the managers of public owned enterprises.

4.24 In the areas of Santa Cruz and Sucre, most of these plants have already been converted to natural gas. In the Altiplano, some of them have provisionally been converted to LPG, awaiting the construction of a natural gas pipeline. A more rapid substitution to LPG has been constrained by insufficient investment in transport, storage and distribution facilities.

4.25 The mission recommends that energy surveys and audits be performed in the largest industrial organizations to identify and quantify the opportunities for energy saving and assist these enterprises in the changeover to natural gas. However, this effort has to be complemented by a revision of the financial performance of public owned enterprises. Many of the industries in which the Bolivian Development Corporation is a major shareholder are uneconomic and are being subsidized and managers have no incentive to reduce costs and save energy.

4.26 It is suggested that the technical know-how required to conduct the energy survey and recommend efficiency improvements should be developed within YPFB, which could provide it as a customer service, assisted by outside consultants. This would also provide valuable information for YPFB in planning for the upgrading its refining and expanding its distribution facilities. Thus the mission recommends that YPFB establish an energy advisory service to promote and assist in the efficient use of energy in all sectors of the economy.

4.27 Within the manufacturing subsector, the sugar industry should be considered as a special case. Energy is used rather inefficiently (para 3.38-3.39) for sugar refining and alcohol production. While sugar production is not expected to increase, the industry has plans to expand alcohol production and to divert bagasse as raw material for a paper mill.

4.28 The mission suggest that three separate studies be made: (a) assessing the present use of energy in each sugar mill and means to increase their efficiency; (b) revising the economic feasibility of increased alcohol production, taking into account alternative uses of molasses and the market for alcohol; and (c) studying the feasibility and location of the paper mill, projected for Tarija, and its impact on the energy requirements of this region.

4.29 The mining industry is a relatively minor (4%) energy consuming sector. It is characterized by its geographic isolation and predominant use of electricity (50% of the sector's requirements). In 1981, about half of the industry's power requirements were purchased from the network, a quarter was hydro-generated and a quarter was generated using diesel sets. Their direct and indirect use of diesel and fuel oil represents about 11% of the total consumption of these fuels. Because of their geographic isolation, substitution alternatives away from liquid fuels are limited. In specific locations mini-hydro, conversion to LPG, and geothermal applications could be developed. However, the priorities of this sector are directed in the immediate future towards increasing productivity to counter rising production costs and intensifying exploration.

(ii) Transport

4.30 Bolivia's internal transportation needs are largely met by road vehicles which carry about 93% of the freight (mostly agricultural products) and 96% of the passengers. Most of the freight and passengers move along a main transportation axis linking the Altiplano cities of La Paz and Oruro, with the valley of Cochabamba and the lowland city of Santa Cruz. Foreign trade depends more on the railroads, which carry about 58% of the exports (largely mineral products) and 81% of the imports. The principal flows are from the mines in the Altiplano towards Chilean and Peruvian ports along the Pacific. In terms of energy, the transport sector depends entirely on petroleum products and in turn accounts for 61% of all final petroleum consumption. Road vehicles consumed 80% of the total, railroads 3% and airplanes 17%. Of additional importance in the qualitative balance is the fact that 58% of all diesel sales are to the transport sector. Both the high energy consumption of the sector and its exclusive reliance on liquid fuels suggest that transport should have a high priority for improving energy efficiency and interfuel substitution, especially among road vehicles.

4.31 The consumption of diesel in transport has increased rapidly, especially from 1975 to 1981 when its share in the road fuel market rose from 15% to 28%. This development was encouraged by the fuel pricing and vehicle import policies of the government. Although diesel prices have now been raised to the same level as gasoline, diesel is still used by about half of the trucks and buses, a majority of which undoubtedly replaced gasoline-powered models. It is recommended that the Government encourage the gradual reduction of the stock of diesel powered vehicles by further raising the price of diesel relative to that of gasoline. Once the pricing incentives are in place, this would permit a gradual loosening of the rigid restrictions on diesel vehicle imports, thus enabling diesel to be used for the sizes and types of vehicles for which gasoline engines are not available. In this connection, the Government's plans for the establishment of a diesel truck assembly plant also need to be reviewed, in view of the possibility that a gasoline (or LPG, CNG or synthetic fuel) powered vehicle may be more economical.

4.32 The use of compressed natural gas (CNG) should be studied in the later part of the decade as a means to advance the use of natural gas. It should be noted that CNG not only has a potential of substituting for gasoline in spark engines, but also successful tests of CNG in diesel engines are currently being made. As an alternative, the use of methanol derived from natural gas has to be examined. Such a study would have to take into account such considerations as the potential demand and storage/filling implications, including safety, training and maintenance requirements.

4.33 YPFB has been selling LPG for vehicles since 1980 and currently serves about 4000 cars and trucks out of six specially equipped service stations. Sales have multiplied from 415 TOE in 1980 to 4073 TOE in 1981. While the current price differential moderately encourages the switch to LPG, the Government is no longer promoting it because of a shortage of LPG at the pump. To minimize the investment required for LPG distribution and retailing in the short term, the effort should initially concentrate on urban use vehicles in the largest cities, such as buses, taxis, car fleets, and short-haul trucks. Later the distribution system could be expanded on a country-wide scale.

Energy Efficiency in Transport

4.34 The energy intensity of transportation has abruptly declined in 1980, possibly as a result of the recent price increases. This limited evidence suggests that the transport sector may be highly responsive to the costs of fuel which, according to a recent study, constitute between 5-19% of its operating costs 1/, and act to reduce those costs. While pricing remains the most important tool for encouraging the efficient use of fuel, the Government can also improve the situation by measures tending to improve traffic flow in urban areas, improving the quality of the road network, and increasing drivers' awareness of energy saving methods. An important step to rationalize the use of fuel in inter-urban freight transport has recently been taken by the Bolivian Government, when it eliminated monopolies in automotive transport.

4.35 An important way in which fuel savings can be achieved is through improving traffic flow in urban areas. The most immediate results could probably be achieved by introducing and enforcing parking and stopping regulations along the main urban arteries, staggering work hours to spread out the commuter rush over a longer period and reduce average commuting time. In the longer run priority lanes for bus services could be introduced in high density routes and some over and underpasses built in main intersections. Considering that these measures involve new investments in traffic control and road improvement, more information is needed before a decision can be made. Thus, it is recommended that the Government undertake an urban transportation study, including a review of energy saving possibilities. This study should complement the ongoing Bank-financed National Transport Study, which has focused on interurban transportation.

4.36 Recent data from the U.S. indicate that changes in the driving behavior of vehicle operators can reduce fuel consumption per vehicle by about 10-15%. These savings have been achieved through training drivers in fuel saving techniques and motivating them to use those techniques. The achievement of those savings do not require any capital expenditure, and basically require the vehicle operators to reduce idling time, maintain proper tire pressure, accelerate more gently, perform periodic maintenance, etc. These techniques are time-tested and generally known, but the problem is to motivate the drivers. In the US this has been achieved through a program of contests and financial incentives. It is recommended that the Government establish a driver training and

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1/ Bolivian National Transport Study, Working Paper 33a, Analysis of Vehicle Operating Costs, June 1980.

motivation program that would enable Bolivia to take advantage of these very economical energy saving opportunities.

4.37 Another source of energy savings can be a sustained effort to rehabilitate the existing road infrastructure and improve road maintenance. The National Transport Study found that much of the network is in poor condition as a result of light construction and deferred maintenance, and the fact that about a third of the trucks exceed the legal axle load limit. That study estimated that a truck consumes about 5% more fuel on a gravelled road than on a paved road and that a similar savings occurs between paved roads in poor and in good condition. Thus, while fuel savings constitute only a fraction of the major (50%-80%) savings in transport costs that can be obtained through road rehabilitation and improvement, these savings are nonetheless important when considering the large volume of fuel consumed in road transport.

(iii) Households and Commerce

4.38 While per capita energy consumption in Bolivia is low by Latin American standards and most households use energy only for cooking and lighting, these energy requirements account for nearly half of the country's final energy consumption. Furthermore, with population growing at 2.5% per year and a gradually rising standard of living, these energy requirements are expected to grow at least as rapidly as those of the rest of the economy. Three quarters of household energy is provided from biomass, which consists of fuelwood in the valleys and lowlands, and shrub and dung in the Altiplano. This will continue to be the predominant household fuel at least for the next decade, although substitution by commercial fuels is likely to increase rapidly, especially in the Altiplano where biomass is extremely scarce and where the fuel with the most rapid growth will be LPG, which is not only substituting for kerosene 1/ but also displacing biomass as suggested by its rapid recent growth rate. About 28% of the households have access to electricity and this proportion should gradually increase as a result of rural electrification. Consumption of electricity in this sector has risen on the average by 20% p.a. over the last six years.

4.39 This sector must be included in the plan to restructure the energy demand. The projected energy balances show that it is likely that the kerosene and LPG available for this sector will not be sufficient to meet projected demand. Therefore, consideration should be given in the short term to introducing gasoline as a household fuel. For the longer term, the gas pipeline projects should be planned so as to permit extending the gas service to major urban areas early next decade. Simultaneously consideration should be given whether substitution by electricity should be promoted.

1/ LPG sells at less than 50% of the price of kerosene, on a caloric basis.

C. GAS PIPELINE NETWORK

4.40 The capital-intensive nature of pipeline projects requires that the routing be chosen to guarantee an adequate initial throughput and that their size and configuration allow future expansion. This implies that the first main lines must be directed to meet markets with fairly concentrated demand, with small seasonal or daily deviations from the average. The GDC study (Annex 1.24) identified the main bulk industrial consumers and their geographic location. The mission adjusted these estimates (Annex 1.25) according to additional information. Table 4.8 quantifies a maximum demand, and compares it with the bulk market, singling out the most energy intensive industries. This information is grouped into specific regional pipeline projects. The bulk market includes the industrial users that can be reached with minimum investment 1/ in a fairly short time. The maximum demand estimate includes a widely dispersed universe of medium to small consumers and it is not yet certain that these can be connected economically.

1/ The investment cost for lateral branches from the main line has been estimated by IDB at US$ 9.1 MM (1981 US$).

Table 4.8: Potential Gas Market
(MMCFD)

Regions	1981 Actual	1990 Baseline Scenario	1990 Moderate Growth Scenario
Altiplano - North			
La Paz, Oruro, Cochabamba			
Maximum Demand	24.4	31.0	34.8
Bulk Market	16.1	21.3	23.2
Altiplano - South			
Sucre, Potosí			
Maximum Demand	5.1	11.0	12.9
Bulk Market	4.1	9.7	9.7
Santa Cruz 1/			
Maximum Demand	17.3	35.9	70.6
Bulk Market and currently supplied with gas	13.6	30.5	57.2
Tarija			
Maximum Demand	1.2	2.5	2.5

1/ The bulk demand includes gas-based power generation. The projection assumes that all future Bolivian requirements will be gas-generated and that all incremental capacity will be installed in Santa Cruz.

Source: Annex 1.25

4.41 In Santa Cruz, a set of pipelines have already been built, which serve the industrial park, ENDE's thermal power plant and a group of industries to the north of the city. Apparently, these lines were constructed individually and do not conform a system designed for long term expansion.

4.42 Camiri and Sucre are being served from the Monteagudo oil field. The line has also been extended to Potosi, to supply the immediate requirements of La Palca (metallurgy) and its associated power plant. The capacity of this regional system is 20.7 MMCFD, well in excess of the requirements of this region. It has therefore been decided to proceed to expansion Phase II, which would connect this branch with the North-South gas export line to Argentina and provide additional supply of gas. To the north it would be extended to Cochabamba, partially using an existing oil pipeline. YPFB further proposes to connect it at Cochabamba with the reconverted line leading to Oruro and La Paz. This whole expansion project is an emergency solution to the pressing need to substitute for fuel oil in the Altiplano, and which was induced by the delay in the approval and disbursement of loan.

4.43 Apparently, YPFB has been able to advance this project as scheduled (it was to be operational by mid-1983). The mission considers that its capacity will be sufficient to provide for the immediate fuel requirement of bulk consumers, including power generation and refineries in the Altiplano region. It would be better to delay the second new pipeline until the growth prospects of the Bolivian industry become clearer.

4.44 The mission's financial analysis (Annex 1.36) shows that under the baseline demand scenario and at a discount rate of 14%, the average transport cost through this line (Monteagudo-Sucre extension) would be US$1.12 MCF.

4.45 The northern Altiplano, with the cities of La Paz, Oruro and Cochabamba, uses 47% of total industrial fuel and 90% of all fuel oil. There is an urgency to supply this region with gas at a competitive rate because the main consumer of fuel oil is the metallurgical sector, which has to compete in international markets.

4.46 In 1980, YPFB negotiated with IDB a loan for building a new Altiplano pipeline. This decision was based on a comparative analysis with the southern Altiplano solution discussed in para. 4.42. It appears that at that time the northern alternative was more advantageous. The southern line was only going to serve the Sucre and Potosi markets.

4.47 The northern pipeline was projected to carry gas from Santa Cruz to La Paz, with intermediate stations at Cochabamba and Oruro. The project has a total cost of US$138.5 million including contingencies and financial charges during construction, for which IDB approved in 1981 a US$97.00 million loan. The proposed line consist of the following elements:

(i) 1 12" diameter, 262 miles long new pipeline between Santa Cruz and Cochabamba, with a total (fully allocated) cost of US$104.8 million;

(ii) the repair and partial replacement of an existing 6" product pipeline, 231 miles long between Cochabamba and La Paz, with a cost of US$7.5 million;

(iii) distribution laterals in main cities, at a total cost of US$9.1 million;

(iv) compressor stations and terminals in Cochabamba and Oruro (US$9.8 million); and

(v) a gas processing plant in Santa Cruz (US$7.4 million). The pipeline was originally planned to become operational during the third quarter of 1984, with an initial throughput capacity of 33 MMCFD and a final capacity of 90 MMCFD. The project has at this stage a delay of at least one year.

4.48 In the meantime, YPFB has modified the design of this gas pipeline and will therefore have to renegotiate the loan with IDB. The main differences between the two designs are:

(a) Gas input: in the new project the pipeline would be fed with the dry gas that exits from the adsorption plant in Rio Grande at a pressure of 1400 psi. This change of origin for the pipeline would eliminate the need to build a new gas treating plant in Palma Solar;

(b) The total length of the pipeline increases to 283 miles, and its diameter is reduced from 12" to 10"; and

(c) the carrying capacity will be 41.4 MMCFD in the first phase, expandable to 60 MMCFD. YPFB has estimated the investment cost for the first phase at US$65 millions (in end-1982 prices), with a foreign exchange component of US$32 million.

4.49 Under the assumption that only major industrial consumers would be connected to the pipeline the financial evaluation of this project shows that at a 14% discount rate, the average throughput cost would be US$1.97/MCF (Annex 1.37). This compares with an estimate of US$0.72/MCF, if the supply were extended to a much wider range of consumers in line with the substitution requirements.

4.50 Should both projects (extension of Monteagudo-Sucre and the original Northern Altiplano pipelines) be implemented simultaneously, then a capacity of about 60 MMCFD will exist for an initial market not exceeding 20-23 MMCFD. The mission recommends postponing the decision for the new pipeline for two years.

4.51 In the south, YPFB has considered the construction of a pipeline that would serve the towns of Tarija, Bermejo, Emborozu and El Puente. It would have an initial capacity of 19.5 MMCFD of gas, either from a deep structure in the Bermejo gas field, where drilling is in progress or from a nearby Argentinian gas field (Ramos). The investment cost is estimated at US$14.5 million for a total length of 240 kms.

4.52 The department of Tarija, located in the southern tip of Bolivia, had an industrial fuel consumption of some 13 MTOE in 1981. There are only a few large consumers scattered in the region: a power station and a glass factory in Tarija and two sugar mills near Bermejo; a paper factory in Emborozu is under construction, which will eventually use bagasse as raw material. The sugar mills argument that the withdrawal of bagasse together with a planned expansion in their alcohol production, would substantially increase their purchased energy requirements. The mission disagrees as indicated in Para 3.39. Finally, there is a plan to build a cement factory in El Puente. The total estimated demand of the region would grow from about 1.5 MMCFD of gas equivalent in 1981 to 2.5 MMCFD in 1990 under the moderate growth scenario. But it would increase to 7.7 MMCFD in the case that all projects be implemented. This is still way below the design capacity proposed.

4.53 The pipeline in Tarija is not only overdimensioned but also based on the demand of industrial expansion projects which are highly questionable. The sugar mills are already being subsidized; the paper mill will initially operate with imported pulp; the requirements of the power stations will diminish when the San Jacinto hydroproject (7 MW) enters into operation in 1983. The mission therefore recommends that this project be postponed.

D. POTENTIAL FOR ASPHALT SUBSTITUTION

4.54 Although this does not have a direct impact on the energy balance, the mission recommends that Bolivia should study the use of sulphur as an agglomerate for road construction, replacing the current asphalt mixture with sulphur up to 50% in weight. The technique of emulsifying sulphur in a hot asphalt mixture has proven to be advantageous in construction and in road maintenance. Pavement tests have shown that it produces denser pavement surfaces, reducing humidity penetration and providing higher resistance and not requiring specialized handling equipment.

4.55 Bolivia's mountain chains have several volcanoes which contain mineral sulphur deposits. There are a few companies, all located in San Pablo de Naper that produce native sulphur in open pit mining. Present annual capacity is estimated to be 215 tons per year 1/. It is necessary to evaluate the cost at which new capacity could be developed.

4.56 Bolivia's annual consumption of asphalt is about 6,000 ton of which one-third for new asphalt cement paving and two-third for road maintenance. Only a very small portion is locally produced and the bulk of requirements have to be imported in drums at a very high cost. The substitution could therefore mean substantial savings of foreign exchange.

Recommendations

4.57 (a) To maintain an adequate level of liquid hydrocarbon supply during the present decade and allow some production flexibility, the envisaged development of

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1/ World Sulphur and Sulphuric Acid Atlas - the British Sulphur.

Vuelta Grande and the enhanced recovery projects at Monteagudo and La Pena should be executed as soon as possible. Also, it is recommended that an LPG extraction facility be built in the Chaco region to allow the processing of gas from Vuelta Grande, Porvenir and other fields. The location of such a plant should be determined through a gas optimization study.

(b) To improve in the short term the qualitative balance of petroleum products, YPFB should consider the possibility of expanding its foreign trade and investigate whether large industrial consumers could safely use imported high-sulphur fuel oils. Furthermore, YPFB should explore ways in which to introduce gasoline as a household fuel in substitution of kerosene. This would make available a larger refinery stream to produce jet-fuel for the aviation industry.

(c) The energy management program has to comprise a monitored shift of demand from liquid hydrocarbons to energy forms which are in more ample supply, higher efficiency in energy use, and adequate economic and financial incentives. Prime targets for the program should be the industrial and the transport sectors.

(d) In the industrial sector energy conversion and conservation activities should be simultaneous, and be based on detailed energy surveys and audits in the major industrial plants. YPFB, assisted by outside consultants, should set-up an internal advisory group to provide technical assistance for defining in each plant the most adequate conversion and conservation projects and for monitoring their execution.

(e) Furthermore, it is necessary to insure that the industries that will be supplied with natural gas are economic, and that their profitability is not artificially increased through an implicit subsidy of gas, by pricing this resource below its opportunity cost.

(f) The sugar cane processing industry should receive special attention in the conservation program. It is necessary to study the efficiency of bagasse use and determine the optimum allocation of surplus bagasse. At the current status of technology, sugar industries should not only be energy self-sufficient, but be net exporters of energy.

(g) The transport sector is the largest consumer of petroleum products and should be given priority in the conservation effort. Substantial savings could be achieved in the short term by improving the traffic flow in urban areas and by increasing the local factors in the interregional freight traffic. It is also recommended that the efforts to rehabilitate the road infrastructure be sustained.

(h) The shift of demand in the transport sector should comprise in the short term: (i) continued ban on the import of diesel-engine vehicles, and (ii) gradual conversion of gasoline motor vehicles towards the use of LPG. In the longer term, the use of compressed natural gas (CNG) or of synthetic fuels should be studied to substitute for both transport fuels.

(i) The present consumption of biomass in the rural areas is insufficiently known. In order to adequately plan for the long term supply of energy for the rural population, it is necessary to carry out extensive energy surveys, evaluating present consumptions and efficiency in energy use.

(j) The simultaneous construction of a new gas pipeline from Santa Cruz to Cochabamba and the extention of the Monteagudo-Sucre pipeline to Cochabamba will result in the short term with an excess capacity that increases transport costs. It is recommended that the Monteagudo-Sucre extension be completed, and that the IDB loan be used for reconverting the existing oil pipelines to gas and for building the lateral branches to supply gas to the major industrial users in Cochabamba, Oruro and La Paz. The decision to build the main new gas pipeline Santa Cruz to Cochabamba should be delayed until 1985-86.

(k) The pipeline project in Tarija cannot be justified and it should not be built in the near future.

(l) The use of mineral sulphur as an agglomerate for asphalt paving should be studied. Potentially, asphalt imports could be substantially reduced.

V. ELECTRIC POWER

Inteconnected Power System

5.01 Bolivia has a total installed capacity of about 500 MW, 62% of which is hydro, 25% is thermal gas-based and the rest (13%) consists of diesel generators in isolated stations (Annex 1.27). The interconnected system is comprised of three zones: North (La Paz) connected in 1980, Central (Cochabamba and Oruro) and South (Potosi, Uyuni and Sucre). The Oriental System (Santa Cruz) is to be connected to the national system by a transmission line to be completed in 1985. With this project, the interconnected system will have a considerable flexibility in the choice of its future primary energy source.

Electric Power Demand Projection

5.02 ENDE's power development plan proposed in 1981 was based on a continued rapid growth of demand: 8.8%/year during 1981/85 and 8.2%/year during 1985-1990. ENDE's forecast assumed that as in the past, the average growth would be led by the expected expansion in the Oriental System, where rates of 16.4% p.a. were estimated for 1981-85 and 11.1% thereafter. The pattern of electricity consumption was expected to change, reflecting a faster growth of industrial consumption as compared with mining consumption. Losses in the system were 7.2% for distribution and 4.7% for transmission during the 1970's. These were kept at the same level in the forecast. A 1983 revision of this plan indicates that energy demand will grow at a slower rate. The new estimates envisage an average growth of 5.2% p.a. between 1982 and 1985 and of 6.5% p.a. between 1985-1990. Still, it is expected that the Oriental System will increase at an higher than average rate (Table 5.1 below).

5.03 The mission considers that the new projection is more adjusted to the current economic reality, which necessarily has to affect the demand of the 4,000 industrial and mining units that purchase 56% of the electricity sold in Bolivia. Similarly, the extension of the services to areas with no access to electricity at present will only be financially possible if the income of these new clients allows them to pay for the service.

5.04 Therefore, the mission suggests that ENDE should periodically revise its demand forecasts, incorporating the changes in economic trends, the performance of major mining and industrial branches, and the effect of tariff adjustments. The period 1981-85 is the critical one. Under present economic prospects GDP in 1985 will still be 2% below the level of 1981, in constant terms. However, if the economy recovers rapidly during the second half of the decade and the large public industrial development projects materialize, economic growth may well be above the 5% p.a. assumed in the mission's baseline scenario. Therefore, the mission adopted in the accelerated growth scenario (Annex 1.7) ENDE's former projection for 1990 as an extreme case.

Table 5.1: Projected Demand for Electricity - 1990

	Actual 1981 2/		1990 Estimates				
			ENDE 3/		ENDE 4/	Baseline Scenario	
	%	Gwh	%	Gwh	GWh	%	Gwh
Mining	31.0	393.7	22	582	n.a.	27	550
Industrial	25.5	323.5	35	925	n.a.	25	510
Rest of Economy	43.5	551.1	43	1137	n.a.	48	978
Total NIS 1/	100.0	1268.3	100	2644	n.a.	100	2038
Other Areas	-	235.1	-	400	n.a.	-	301
Total Demand		1503.4		3044	n.a.		2339
Losses	16	173.9	13	455	n.a.	13	349
Gross Generation		1677.3		3499	2811		2688
Rate of Growth (1981-90) %				8.5	5.9		5.4

1/ National Integrated System. The Oriental System, which will be integrated into NIS by 1984, is included in the 1981 NIS total.

2/ Figures changed according to information contained in the Draft Electric Plan - 1983.

3/ ENDE's estimates made in 1981.

4/ ENDE's estimates made in 1983.

Source: For 1981 and 1990 ENDE: Annexes 1.28, 1.29, 1.29A.
Mission baseline scenerio: Annex 1.04.

Expansion of Generating Capacity

5.05 Although the long lead time involved in power projects makes it advisable not to use too conservative estimates of future demand which may leave ENDE with inadequate reserve capacity, the company is currently reassessing its expansion projects, with the purpose of postponing the largest investment commitments until the economic prospects become better defined. The revised expansion requirements are estimated by ENDE at 161 MW for the period 1983-1990. This compares with the former estimate of 300 MW. This new figure matches the estimates made by the mission (Table 5.2).

Table 5.2: Forecast - Bolivia's Total Gross Generation & Demand

	1980	1990
ENDE's (Accelerated growth scenario)		
Gross Generation Requirements (GWh) 1/	1,565	3,499
Maximum Demand (MW)	322	719
Baseline Scenario		
Gross Generation Requirements (GWh) 1/	1,565	2,688
Maximum Demand (MW)	322	560
Scenario Differences		
Generation Requirements (GWh)		811
Maximum Demand (MW)		159
Total Effective Existing Capacity (MW)	406	
Additional Capacity Required: (1980-1990) 2/		
ENDE's Projection (MW)		313
Baseline Projection (MW)		154

1/ Losses in transmission and distribution assumed 13% of gross generation.

2/ Net generation capacity, without considering capacity reserve, which should be at least 15% of peak demand.

5.06 Another source of uncertainty for the power development program resides in the choice of the primary energy source. Chapter 3 has already provided information on Bolivia's considerable hydro-potential, that has on the average an estimated investment cost of US$2,000/kW, and on a specific identified source of geothermal energy which could also be developed. In addition, a transmission line is being constructed between the eastern power system and the interconnected central system. This opens the opportunity of choice of developing the hydrocapacity in the valleys or increasing gas-based thermal power generation in the east.

5.07 The choice among these alternatives is a function of the cost of capital and of the price of gas. At a low opportunity cost for capital and at international prices for gas, the renewable energy sources become the least cost solution for the expansion. However, the financial constraints in Bolivia suggest a rather high opportunity cost for capital and the price at which incremental quantities of gas could be exported has not yet been defined and could be lower than the international price, both conditions resulting in a least cost solutions favoring thermal generation. To illustrate this point, in Table 5.3 below, the cost of the hydropower project of Sakahuaya (the first to be built in the development program with a cost of US$2,083/kW) is compared to gas-based thermal alternatives. A gas turbine has the lowest effective investment cost (US$400/kW) 1/ of all, but operates at a less efficient rate than combined cycle plants. The option of a combined cycle station in Cochabamba is also included in the comparison, to illustrate the alternative of transporting gas from Santa Cruz to Cochabamba to generate electricity there.

Table 5.3: Hydro Versus Gas Power Development
Sensitivity to Discount Rates and Gas Prices

Generation Cost and Break-Even Gas Prices

	12%	14%	16%
Hydro Power Sakahuaya Generating Cost (US¢/kWh)	5.20	6.01	6.83
Cochabamba Combined Cycle Break-Even Gas Price (US$/MCF)	2.36	2.93	3.51
Santa Cruz Combined Cycle Break-Even Gas Price (US$/MCF)	3.13	3.78	4.44
Santa Cruz Gas Turbine Break-Even Gas Price (US$/MCF)	3.33	3.91	4.51

Source: Annex 1.30.

5.08 The-break even price for gas so determined indicates that, at a 12% discount rate, the construction of a gas turbine in Santa Cruz is justified if the opportunity cost for gas is below $3.30/MCF; at a 14% discount rate (which is more in line with the present financial situation of Bolivia) this price rises to US$3.90/MCF.

5.09 ENDE's 1981 least cost expansion program for the period 1982-87 included mostly hydroelectric projects, which were selected assuming international prices for energy products. In view of Bolivia's uncertain economic growth prospects, its balance of payments difficulties and the fact that at present the opportunity cost of natural gas is not likely to exceed US$3.30/MCF, the mission recommends that generating capacity expansion in the immediate future be gas-based. The combined effect of lower demand expansion and gas-based incremental generation would reduce ENDE's generation investment requirements from approximately US$600 million to US$120 million for the rest of decade. However, hydropower

1/ An availability rate of 75% is assumed for gas turbines. The investment cost used refers to effective capacity and not the installed capacity cost.

projects must be phased in once the financial constraints ease and economic growth stabilizes, in order to maintain the gas reserve/demand balance (Table 8.1), in the case the gas export project to Brazil is implemented.

5.10 There is another reason for suggesting that the hydropower projects be postponed. Recent information presented by an UNDP financed study 1/ suggests that Icla and Misicuni hydro power projects require some important design changes, and that investment costs could be higher than present estimates. Moreover, the consultant suggests that there may be other lower-cost solutions, involving construction of power-only projects such as San Jose and Rio Zongo.

5.11 Most of these arguments have been incorporated by ENDE in the 1983 Power Expansion Plan. According to the reassessment made, the energy and peak demand can be met until 1986 with the capacity additions currently being constructed. (These include a fourth unit of 18 MW to be added to the Santa Isabel hydropower plant (1984), the enlargement of the Corani reservoir (1984), and an additional 22.8 MW gas turbine in Santa Cruz (1983). Alternative expansion options are being considered for 1986-1990, including single purpose hydroelectric projects and gas power projects. The mission considers that the proposed plan is reasonable and that ENDE should complete the economic and financial analysis of the alternatives, to arrive at a least cost investment program. At the same time, the mission suggests that ENDE should obtain technical assistance to revaluate its multiple purpose hydropower projects and to update the construction costs of all the projects should be updated, using a uniform normed cost approach. This would imply developing a cost manual for Bolivia, with proper adjustments to the specific conditions of each region.

Power Generation in Isolated Systems

5.12 The isolated and rural power systems do not have a flexibility of choice. A continuous study must be made to assess new alternatives. In some cases, the issues are clear, and the mission makes the following recommendations.

(a) Villamontes: ENDE has installed two dual-fuel thermal units, rated 1,200 kW each, served from the gas pipeline to Argentina; service is provided to approximately 3,000 people. Since the gas supply to this part is ample, generation expansion should be continued on the same basis.

(b) Yacuiba: ENDE provides service to about 13,000 people, using purchased power from Argentina, limited for technical reasons to 1,000 kW. Negotiations should continue with

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1/ "Comparacion Tecnica de Proyectos Hidroelectricos en Bolivia" by Pierre Meystre, Consultant, Switzerland, March 1982.

Argentina to increase the amount of power available to satisfy future expansion of the demand.

(c) Bermejo: SETAR provides service to 6,500 inhabitants from a 600 kW diesel plant. The alternative of power purchases from Argentina should be investigated, to substitute existing plant and cover the expansion of the system.

(d) Camargo: ENDE has installed two diesel power plants, rated 500 kW each, to serve 10,000 people. When justified by the demand growth, this town should be connected to the NIS (Southern System).

(e) Tarija: ENDE has installed 5,200 kW in diesel plant, and the Asociacion San Jacinto of which ENDE is a partner, has started the construction of the multi-purpose San Jacinto hydro-project, which would permit ENDE the generation of 7,000 kW. Because of the importance of this system, it should be connected to the NIS by 1990.

(f) Trinidad: ENDE is in charge of the service to this town of 15,000 people, installed capacity is 2,000 kW in diesel-generation. Studies made by ENDE with the assistance of a consultant ruled out the possibility of using wood as an alternative to diesel-fired plants, because of the great distances which firewood would have to be carried, difficulties in transport during the rainy season (seven months per year), etc. Since no hydro sites appear possible in the area, the system would have to continue its expansion based on diesel-plants until other forms of generation are possible (biomass, solar, wind power, etc.).

(g) Pando Area: The northern Departamento del Pando, with its capital Cobija, has several small diesel installations, operated by the Corporacion de Desarrollo del Noroeste. ENDE should continue studying possibilities of installation of some hydro-plants to substitute partially for thermal generation in the area.

(h) Rural Electrification: The Instituto Nacional de Electrifacion Rural (INER), an agency of the Ministry of Energy, responsible for providing electricity to isolated villages and small towns, has so far provided installations, mainly diesel plants, to some 50 villages. In addition, the local distribution companies have programs to extend their distribution lines to the neighboring rural areas. ENDE has also invested considerable amounts of money in the construction of some 4,500 km of primary and secondary lines, installations which are normally handed over, at the end of its construction period, to the local distribution company or local institutions. The management of current operations as well as future decisions relating to new investments should be reviewed in the context of a comprehensive plan.

Recommendations

5.13 (a) Complete the economic and financial analysis of the new power development plan and arrive at a flexible and coherent optimum solution for the 1986-1990 power generation expansion.

(b) The choice between natural gas and hydro-based expansion of the generating capacity depends on the decision of the gas export project to Brazil.

(c) Obtain technical assistance to evaluate the changes in design recommended by the UNDP consultant for the multi-purpose hydropower projects of Icla and Misicuni.

(d) To update and uniform the cost information on ENDE's project list, the company should develop a cost manual for Bolivia, with proper adjustments to the specific conditions of each region.

(e) In isolated power system, new alternatives should be continuously studied to reduce their dependence on diesel oil. In the rural area, the management of current operations and future investments in power should be reviewed in the context of a comprehensive rural electrification plan.

VI. REFORESTATION AND POTENTIAL FOR SMALL SCALE RENEWABLE ENERGY USE

6.01 Bolivia has considerable forest resources and exports about 90M m^3 of high quality wood products per year. However, these resources are located mainly in the scarcely populated tropical lowlands. In the Altiplano, there is practically no remaining forest cover and the dense population relies on shrubs and animal waste to satisfy their energy requirements, with consequential adverse effects on the already highly eroded environment. In the southern tip of Bolivia (Tarija), uncontrolled past deforestation has caused an erosion problem of major proportion. In the valleys, wood is being exploited more rationally and the population has interest to increase their agricultural revenue by reforestation.

6.02 The use of fuelwood and other biomass by the rural population is insufficiently known. Only in 1980 was an OLADE-sponsored survey initiated, which covered 32 villages in the valleys and semitropical areas of the La Paz department and one village in the Beni Department. Based on the results of this survey and with the use of information from other Latin American countries, the Ministry of Mines and Hydrocarbons estimated a daily per capita consumption of 1.9 kg in the Altiplano, 2.5 in the valleys and 3.1 in the tropical lowlands. The mission consideres that these figures are too high. The experience in other countries indicate an average daily per capita consumption varying from 1 to 1.5 kgs. It is not clear whether these figures represent only household consumption or whether the differences also account for industrial use of fuelwood. Total fuelwood consumption is estimated at 2.1 MMton in 1980, of which 42% is in the Altiplano and 29% each in the valleys and the lowlands. It is recommended that the survey of fuelwood consumption be extended to obtain more reliable data for the reforestation projects.

A. FUELWOOD

Altiplano

6.03 Unconventional technologies, such as biogas, windpower and solar energy, are expensive relative to the income of the rural household and require a social and technical environment that can only be brought about through continuous technical support. Furthermore, the climate of the Altiplano limits considerably their potential to serve as fuel for cooking. The mission therefore recommends that the energy problem of this region be treated as a part of integral rural development programs and energy technologies be adapted taking into account the conditions of each location.

6.04 Agricultural research should be addressed to increase plantation of multi-purpose crops. For example, there is a species known since pre-colonial times in the Altiplano that provide high protein grains, has celulosic stems that can be used as fuel, and fixes nitrogen to the soil: Chemopodium Quinoa, a leguminous plant. Modern research to increase productivity of these plants and to find processes for expanding its markets (it has a potential to substitute for wheat) are necessary.

6.05 Reforestation has proven successful in the Omasuyos/Los Andes project which is currently being implemented. This is a part of the program of the Altiplano Rural Development Institute (IDRA) funded by the World Bank. The forestry component aims at reforesting areas in those two Altiplano provinces for production of fuelwood and local construction materials. Species trials to identify new trees which would survive the harsh Altiplano climate will also be carried out. In the meantime, conifers and Eucalyptus grandis will be planted with emphasis on the more favorable micro-climate near Lake Titicaca. The project has been very successful in developing demand by individuals and community groups for seedlings and technology for establishing small temporary nurseries and for planting trees. The demand for seedlings already far exceeds the capacity of existing government nurseries. Expansion of a CDF nursery near Huarina from a capacity of 200,000 seedlings per year to 600,000 will therefore be carried out in 1982 by the Project Unit in agreement with the CDF. Field visits to the existing nursery and various planting sites revealed considerable local interest in the planting program.

Tarija

6.06 In this eroded southern part of Bolivia, a soil recuperation program is being executed (PERTT). This program is using the approach of assisting rural community groups in the establishment of their own small nurseries with a production of around 30,000 plants per year for use by the group members. Since these communities become actively involved in their own seedling production, they have an inherent interest in planting the trees well. PERTT gives the necessary technical assistance for establishing the nurseries, provides the communities with seed and materials and gives technical advice for planting. It also maintains several larger nurseries (capacity about one million seedlings per year each) in the Tarija Valley, which produce seedlings for sale and/or for planting on public lands. While the program has been a technical and economic success, it is still a small-scale program compared to the area's needs. Although just under 500 ha were planted in the three-year period 1978-80, it has been estimated, with the aid of aerial photographs, that over 70% of the Tarija Valley's soils are "severely" eroded and that agricultural and grazing lands are being lost at the rate of over 800 ha per year. FAO evaluated the situation in Tarija and recommended a strong soil conservation program based on intensive extension, services to improve pastures and grazing and cultivation practices. Small woodlots and strategically located industrial forest plantations would take pressure off the few remaining wooded areas for supplying fuelwood, local construction needs and industrial wood needs. This, plus protection from over-grazing, would allow the eroded hillsides to regenerate naturally in a relatively short time (3-5 years). Civil works (check dams, river bank gavions, etc.) and reforestation in critically eroded areas would also be needed.

6.07 The mission suggests that PERTT program be investigated as a potential rural development program with emphasis on low-cost, efficient soil conservation activities and the establishment of woodlots for domestic fuelwood and construction needs, industrial charcoal production, and industrial roundwood (a newly built pulp and paper mill does not have sufficient wood raw material to operate at capacity and wood pulp must be imported from Chile).

Chuquisaca

6.08 Another reforestation and conservation project is being developed by the Chuquisaca Regional Development Corporation (CORDECH) exclusively with Government funds and local technology. It has been highly successful in developing a reforestation/conservation awareness in the rural population of the region. The social and economic importance of the program is significant.

6.09 The Department of Chuquisaca is largely of forestry vocation in that its soils in general are not suitable for sustained agricultural activities. Many farmers have abandoned their land and moved to lower tropical areas to the east where malaria and other diseases have taken a heavy toll. Much of the area of Chuquisaca was covered with large valuable cedars of which only a few specimens remain. These and other trees were cut for mine timbers, construction wood and firewood and charcoal for smelting silver, gold and tin. As a result of this cutting and a rigorous environment which makes natural regeneration difficult, the area is now almost completely deforested. Local ceramics (roof tiles, bricks) companies, mostly small operations, are purchasing firewood from about 60 km away. This fuelwood accounts for almost 25% of the production costs of tiles and could be produced in small woodlots near the ovens. This is one of the objectives of the reforestation program. By promoting reforestation, CORDECH is creating immediate employment in the planting activity. The forests have excellent growth rates and will provide cash income to the rural population. Agricultural activities will supply enough food for subsistence. There are already examples of families who have returned to the land they have previously abandoned and wish to reforest it. The benefits in terms of soil conservation and improved water flow and quality are also expected to be great. Demand for seedlings already exceeds the two million trees per year capacity of the program's nurseries.

6.10 A US$1 million project funded by IFAD will establish ten new nurseries in three additional provinces to the south of Sucre (Oropeza, Yamparaez, Zudanez). This is a successful program which needs technical assistance to improve its nurseries, species selection, reforestation techniques and monitoring activities and needs financing to expand into new rural areas. The FAO Forestry Department has agreed to provide technical assistance, although fielding of specialists has been delayed now for nearly a year. The successful methodology developed for promoting reforestation, the good growth rates being obtained with Eucalyptus grandis and Pinus radiata (over 5 m^3/ha/yr) plus good markets for industrial and domestic fuelwood, pit-props and industrial roundwood are factors which make this an excellent project, for which external financing should be requested.

B. CHARCOAL

6.11 Charcoal consumption is estimated at 25,000 tons per year. Over 85% of the charcoal consumed in Bolivia's tin smelting industry, (as a reducing agent) comes from the Santa Cruz and Chaco regions. The average transport distance is over 1,000 km by dirt road. Essentially 'free' wood from residues of crosstie manufacture in the Chaco and from land clearings near Santa Cruz, together with lack of raw material closer to the smelting center in Oruro allow the long distance transport to continue despite its heavy costs and energy consumption. The transport cost of the charcoal is equal to its value at the charcoal producing site ($b2,500/ton). Discussions and visits with the Charcoal Producers Association (ANICARVE) and the consuming smelter (ENAF) indicated that the charcoal producers are not efficiently organized with respect to timber harvesting. Large, high-value logs are converted to relatively low value charcoal for: lack of industrial infrastructure in the rural areas (small sawmills); lack of markets for logs for crossties and sawnwood (economic recession); lack of proper harvesting and transport equipment (trees are cut and bucked with saws and loaded by hand). Also, a rather unusual division of labor leads to cutting of large trees. One group cuts the trees and has a quantity quota which can be made up quickly by cutting a few large trees. Another group loads the trees onto trucks and must contend with manipulation of the large logs. The ANICARVE group requested a line of credit for investments in small sawmills and harvesting equipment. They also requested technical assistance for improving utilization of their forest resources. As a result of this visit, the mission contacted the US Forest Service, which was organizing a seminar on charcoal manufacturing for USAID in Brazil. The Brazilians are very advanced in industrial charcoal production and offered the course for other countries to attend. The result of this contact was that the President of ANICARVE attended the seminar in March 1982.

6.12 Because of the wood resource supply/demand situation, the Santa Cruz area will be the center of charcoal production for at least five to ten more years despite its distance from the principal market. The charcoal producers should therefore be given technical assistance to improve the efficiency of their industry and provide lines of credit to purchase capital equipment to modernize their operations if studies show this to be feasible.

6.13 In the meantime, the Government should develop a reforestation program with fast-growing fuelwood species near the Oruro area in order to guarantee supplies of charcoal ten years hence at lower cost to the smelter. Species and planting trials should be initiated as soon as possible in the Oruro area and in the now deforested traditional charcoal supply areas nearby.

Wood and Charcoal Stoves

6.14 The long existing scarcity of fuelwood in the Altiplano has induced the design of a locally produced stove which appears to be energy efficient. It is made of clay and sand and the top hole fits perfectly the convex shape of the cooking pot's base. In the lowlands, more primitive stoves are used. It is recommended that the traditional stove of the Altiplano be evaluated. Should the tests confirm its efficiency, a program should be developed to adapt it to the rest of the country. This would be a means to create a new cottage industry in the Altiplano.

COMPONENTS OF AN FOREST-BASED ENERGY DEVELOPMENT

6.15 It is recommended that a forest-based energy development project for Bolivia should comprise several components:

(a) reforestation for charcoal production in the Oruro area. A feasibility study would have to be undertaken to determine: planting sites; species to be planted (this information to be improved by a species elimination and trials program included in the project); methodology and detailed costs of planting; and delivered cost of charcoal to smelter. Strategically and economically this is potentially the most important reforestation program which could be developed for Bolivia. The responsibility for developing this project would have to be determined (CDF and/or ENAF and/or regional development corporation for Oruro);

(b) technical assistance for and expert evaluation of the forestry, charcoal manufacturing and charcoal transport activities in Santa Cruz. Depending on consultant recommendations, lines of credit would be opened to mechanize and modernize these operations;

(c) project for an expanded reforestation project in the CORDECH area for fuelwood production for domestic and industrial needs and for industrial raw material production;

(d) expansion of the Omasuyos/Los Andes forestry project and the development of similar projects in other Altiplano regions to produce fuelwood. This would substitute the burning of dung which could be used for fertilizer. A strong species trials component would be necessary for selecting trees resistant to the rigorous Altiplano environment. The data generated by the MEH/OLADE fuelwood survey would be the basis for determining areas with critical fuelwood shortages;

(e) preparation of a forest energy and soil conservation project in the heavily eroded Tarija Valley. Plantations for charcoal and pulpwood production would also have markets according to contacts with Tarija groups. The FAO suggestion for establishing a charcoal for export (to

Argentina) firm in the Chaco region of Tarija should be investigated;

(f) research to increase plantation of high protein crops (such as Chemopodium Quinoa and other leguminous plants) in the Altiplano, which would simultaneously provide food and fuel and help stem the erosion problem and fertilize the soil;

(g) minimum investment requirements to execute these projects are estimated at US$30 million, allocated in the following manner: (i) expansion of the Omasuyos/Los Andes projects US$ 7 million, including applied agricultural-forestry research; (ii) extension of the Chuquisaca reforestation and conservation program US$4 million; (iii) soil conservation project in the Tarija Valley US$10 million; (iv) technical assistance to industrial charcoal producers US$1 million; (v) establishment of a tree plantation near Oruro for the production of industrial charcoal US$8 million.

VII. MAJOR POLICY IMPLICATIONS

7.01 Major policy changes are necessary to enable the energy sector to cope with the task of supplying future internal energy requirement and increasing its contribution to foreign exchange earnings. To place these issues in the proper perspective, the first section of this Chapter sums up the main investment categories previously discussed. It then analyzes energy pricing and institutional issues that have to be resolved.

A. ENERGY INVESTMENTS

7.02 The share of the consolidated public sector's capital expenditures has decreased from 15% of GDP in 1977 to 5.7% in 1980. In 1981, these investments amounted to the equivalent of some US$385 million or 6.6% of GDP. During the period 1982-85, it seems prudent to assume that the Bolivian economy will not be able to sustain an annual public investment program of more than 7% of GDP or some US$400 million (in constant 1980 prices), given the poor economic outlook and the fiscal constraints. Should GDP grow at 5% in real term after 1985, then the investment capacity will have to increase at a higher rate. To establish a reference mark with which investment requirements on the energy sector can be compared, the mission assumes that average total public investments during the period 1986-90 will be US$500 million per year.

7.03 The investment plans for 1981-86, submitted by the energy corporations in 1980, estimated total capital expenditures of US$2,073 million in constant 1980 prices (YPFB US$1,553 million and ENDE US$520 million). This would represent an annual outlay of US$415 million, which clearly exceeds the present capability of the Bolivian economy. To assist the Bolivian Government in the difficult process of screening priorities and allocating scarce resources to the most fundamental projects, the mission reviewed the investment programs of each energy corporation.

7.04 The decision on the gas export project to Brazil is the most important determinant of the sector's investment requirements. Firstly, it would accelerate economic growth and therefore increase the levels of internal energy demand. Secondly, it would require a direct investment in gas production and transport facilities of about US$800 million, which is roughly equivalent to 50% of YPFB's investment program. Thirdly, the hydro-based alternative would become the least cost solution for expanding the power generating capacity. The combined effect of higher demand for power and the choice of the hydro-option would increase ENDE's investment expenditures in generation from US$120 to US$600 million (para 5.09) for the period 1982-1990.

7.05 The mission adopted two investment scenarios:

(a) The decision to implement the gas export project is not taken; and

(b) An early positive decision on this project is reached.

Both scenarios are divided into two four and a half years periods: 1982-86 and 1986-90. The mission included not only those projects listed in the energy corporations' development plans, but also additional investments that have been discussed in previous chapters. The results are summarized in Table 7.1.

No Gas Export Pipeline

7.06 Due to the much lower than expected growth in energy demand during 1981-85 and an estimated more moderate growth during the second half of the decade, it is safe to assume that the levels of energy demand estimated for 1986 on which the investment plans were based will not be reached but at the end of the decade.

7.07 Total energy investments under this scenario are estimated at US$1,012 million, with an average annual expenditure of US$82 million during the first half of the period and US$142 million during the second. This represents 21% and 28%, respectively, of the total public investment for the two periods.

7.08 YPFB's minimum capital requirements were estimated at US$181 million for period 1982-86 and at US$406 million for the second period. These figures are based on the criteria that no exploration would take place until mid-1986 and then only half of YPFB's program would be excuted. Development of fields would be limited to Vuelta Grande during 1982-86, Espino and half of the new fields development program would be carried out in period 1986-90. Production drilling and secondary recovery projects would be executed as planned. In transport, the extension of the Monteagudo-Sucre gas pipeline and the repair of the Cochabamba-La Paz line would be implemented to enable substitution by gas in the industrial sector of the Altiplano before 1986, and some natural gas distribution networks would be built after 1986 to enable substitution of other consumers in the major urban areas (Annex 1.37).

7.09 ENDE's capital requirements are estimated at a total of about US$293 million (US$113 million for 1982-86 and US$180 million for 1986-90). These include ongoing works as indicated in Annex 1.10, comprising some hydropower projects and the transmission line between the oriental and central electric systems. Also allowance is made for distribution networks, which are not included in ENDE's investment budgets. It is estimated that during 1986-90, demand for electricity would grow as estimated by the mission under the Baseline Scenario (Table 5.1) and that capacity expansion would be gas-based.

Table 7.1: Investment Requirements Energy Sector
(1980 prices - million US$)

	Development Programs	1982 - 1986 Without Pipeline to Brazil	1982 - 1986 With Pipeline to Brazil	1986-1990 Without Pipeline	1986-1990 With Pipeline
Supply					
Hydrocarbons					
Exploration	296	-	25	177	271
Development	515	98	222	169	293
Processing	79	0.3	0.3	-	3
Transport	571	47	485	3	119
Marketing	92	35	35	57	57
Studies	-	4	8	-	-
Power					
Generation	477	70	70	120	450 1/
Transmission	43	43	43	-	-
Distribution	-	35	35	60	60
Reforestation and Research	-	10	10	20	20
Demand					
Conversion - conservation study		2	2	2	4
Private investment in equipment		20	20	30	30
Institutional Strengthening, Training		10	10	5	5
TOTAL (constant 1980 prices)		369.3	965.3	643	1312

1/ Based on demand projection for electricity as estimated by mission. Under ENDE's set of projections this would increase to US$600 million.

7.10 Further capital allowance has been made for investment in reforestation (US$30 million), in energy conservation (US$54 million), and in institutional strengthening (US$10 million).

With gas export pipeline

7.11 Under this scenario, the mission considers that the financial restrictions will remain, and that only those investments directly or indirectly related to the gas export pipeline should be made. Even under this conservative approach, the amount of financial resources required become extremely high. Investments are estimated at US$965 million during 1982-86, or US$214 million per year, more than half of total public capital resources. During 1986-90, they amount to US$1,312 million, equal to almost US$300 million per year or 60% of public capital expenditures. These figures indicate that substantial foreign financial assistance is required and that it would be convenient to consider ways of increasing private participation in the development of the energy sector.

7.12 YPFB's capital requirements were estimated at US$770 million during the first period and US$740 million during the second. During 1982-86 only minimal exploration is included, the development of the Boomerang fields and the construction of the gas export pipeline. In the second period, YPFB's projected exploration and development program is fully implemented and it is also assumed that the new Santa Cruz-Cochabamba pipeline would be built. The mission has, however, excluded the investment in the ammonia-urea complex, considering that it should be postponed to the 1990's.

7.13 ENDE's investment needs are estimated at US$658 million for 1982-90. The considerable increase over the first scenario (para 7.09) are due to the choice of hydro development over gas-based capacity expansion. The demand projections on which the second period investments are based are the same as in the first scenario.

B. ENERGY PRICES

7.14 Two crucial pricing problems confront Bolivia. The first refers to the absolute price level which determines the income of the energy corporations and their capability to remain in business. The second relates to the relative prices of the various energy forms which must be structured so as to give the right incentive to shift demand towards the more abundant energy sources.

1. Absolute Prices:

7.15 Bolivia is undergoing a readjustment of its internal price structure. While the Bolivian peso was devalued and the foreign exchange rate has increased by 700% 1/ since January 1982, its internal inflation

1/ On November 6, 1982, the Government reunified the exchange rates to $b200/US$.

rate was only about 110% from January to August 1982. The difference between the two rates gives an indication of the high social cost of this readjustment, and permits understanding of Government's reluctance to carry it beyond tolerable levels.

7.16 Both energy corporations (YPFB and ENDE) have been hurt by these events. However, their immediate financial position differs considerably. The power corporation depends on domestic revenues which have been increased by a total of 517% (in February by 54%, and again in November 1982 by 300%) while its investment program has probably increased by 460% 1/ and its current expenditures by 100%.

7.17 YPFB's financial position has nominally improved because of the large component of export revenue in its total sales revenue. 2/ However, it is not clear whether the Government allowed the corporation to retain these earnings.

Oil Product Prices:

7.18 Bolivia is no longer a surplus petroleum producer and it is in the country's interest to encourage conservation and to accelerate the transition towards a balanced pattern of energy consumption. To achieve these objectives, prices should signal to consumers the opportunity cost of using petroleum products. This cost should reflect the relative scarcity of each product in the domestic market; that is, full net-back value (fob) obtainable from exporting products where there is still a supply surplus (basically napthas, gasoline and LPG), and fully expensed import cost for deficit products such as diesel and fuel oil. In the longer term prices must reflect the full import cost.

7.19 In the course of 1982, the price of petroleum products rose substantially in nominal terms, but declined in real terms as a result of rapid inflation and the depreciation of the Bolivian peso. Thus, the economic measures taken in February meant that the price of the composite barrel declined from US$34 and US$27. From that level, the real price fluctuated downwards to a minimum of about US$5.90/bbl. The new economic measures imposed in November resulted in a major increase to about US$16/bbl. However, this is still less than half of the opportunity cost of US$37/bbl, as shown in table 7.2 below.

1/ Assuming 60% foreign component at an average devaluation rate of 700% and 40% domestic at 100% inflation.

2/ Annex 1.32 estimates that the operational revenue has increased from a budgeted surplus of US$180 million to US$370 million with the double exchange rate.

Table 7.2: Petroleum Product Prices: Retail vs. Opportunity Cost
(US$/bbl)

	1981 Shares in Total Sales % 3/	Opportunity Cost 2	Retail Price 1981	Feb. '82 1/	Nov. '82
Gasoline Premium	1.3	36.26	44.52	36.14	27.83
Gasoline Superior	31.3	33.47	38.16	28.91	19.88
Kerosene	7.6	47.60	25.44	18.07	6.36
Diesel Oil	21.6	42.17	38.16	28.91	18.29
Fuel Oil	11.2	43.06	34.98	27.10	17.49
Jet Fuel	2.0	47.60	54.60	57.27	61.74
Jet Fuel LAB	5.4	47.60	54.60	57.27	n.a. 5/
Avgas 100 Oct.	1.3	66.08	84.00	62.05	21-36.75 6/
LPG Domestic Use	15.5	22.98	10.30	6.83	2.18
Industrial Use	0.8	22.98	10.11	8.78	6.12
Automobile	0.5	22.98	19.08	18.07	11.93
Average Barrel 4/	98.5	37.30	34.03	26.84	16.26 (19.25) 7/
INDEX		100.0	91.2	72.0	43.6

1/ Conversion made at the official exchange rate of $b44/US$.
2/ Import price of products that are scarce (diesel, fuel oil) and FOB export netbacks of products that are in more ample supply (LPG, gasoline, Avgas), based on Platt's Oilgram, March 24, 1982; general purpose tanker rates at 190 WS and actual 1981 overland transport costs.
3/ Shares as indicated in Annex 1.17.
4/ About 1.5% in volume consist of non-energy products sales.
5/ The price for Lloyd Aereo Bolivianos has not yet been decided.
6/ The lower price is for meat transport flights.
7/ Composite barrel excluding LPG.

7.20 While Government has succeeded in raising prices above the fully expensed cost level of about US$16/bbl and thus insured the financial viability of oil operations in the short term, prices are still far from reflecting the true economic value of oil. The mission recognizes the giant step already taken. At the same time, it recommends that the Government adopts opportunity cost as the pricing principle and adjust prices gradually and periodically at a higher rate than internal inflation to achieve its objective level as soon as possible.

Power Rates:

7.21 Power rates underwent the same pattern of increase in nominal terms associated with a decline in real terms as shown in Table 7.3 below.

Table 7.3: Bolivia: Average KWh Prices of Electricity
(Current Prices per average kWh)

Companies	1980		1981		Feb. 1982		Nov. '82	
	$b	US¢	$b	US¢	$b	US¢	$b	US¢
ENDE (Bulk sales)	0.69	2.8	1.20	4.8	1.85	4.2	7.40	3.70
BPC (La Paz)	0.82	3.3	1.35	5.4	1.51	3.4	7.10	3.55
CRE (Santa Cruz)	1.15	4.6	1.78	7.1	1.96	4.5	7.50	3.75
ELFEC (Cochabamba)	1.11	4.4	1.70	6.8	1.88	4.3	7.10	3.55
CESSA (Sucre)	1.21	4.8	1.66	6.6	1.84	4.2	8.16	4.08
SEPSA (Potosi)	1.42	5.7	2.00	8.0	2.18	5.0	7.50	3.75
SETAR (Tarija)	1.64	6.6	2.39	9.6	2.57	5.8	7.50	3.75

7.22 ENDE confronts a very strained financial position. Although the Electricity Code guarantees a 9% rate of return, the corporation achieved a 6.8% rate of return in 1981. The mission recommends that the financial situation of ENDE be reviewed and that the bulk sales tariff be increased in accordance with the scheduled increases in the rates of return, that would permit an agreed average self-financing ratio of 44% for the period 1981-86. 1/

Long Run Marginal Power Costs (LRMC)

7.23 Previous studies made by the Bank 2/ indicate that ENDE's bulk rates should be based on the LRMC, which would allow the generation of local funds to finance up to 44% of the expansion program. For ENDE's least-cost solution based mainly on a hydroelectric development, the LRMC, calculated in an approximated way by the average incremental

1/ Simons Resource Consultants in a preliminary review of the power sector recommend that the National Electrical Code should be amended to allow for interest charges on overdue accounts. (Guaranted rate of return to be increased from 9% to 15%).

2/ ENDE V. POWER Project - Staff Appraisal Report No. 3617-BO.

cost, in constant currency, at a discount rate of 12%, was US¢5.85/kWh. 1/ This compares to an average tariff of US¢3.7/kWh. This indicates that tariffs have to be increased by at least 58% to allow meeting ENDE's objectives.

2. Relative Prices:

Hydrocarbons

7.24 The relative prices of oil products and natural gas must be structured so as to give the right incentives for interfuel substitutions. The price of gas should reflect its production and transport costs (without the pipeline to Brazil), or its opportunity cost (with the pipeline to Brazil). Fuel oil and diesel prices must be increased to those of gasoline in energy equivalent terms to reflect their scarcity. Simultaneously, the kerosene price and the price of domestic LPG should be increased to avoid their use as substitute fuels in the industrial sector. To provide a comparator for the price of gas, the following estimate of the long term incremental costs has been made.

Incremental Gas Production Costs:

7.25 An economic distinction should be made between gas produced in condensate fields and gas from mainly gas fields. The former are developed because of the associated condensate and because of their relatively high content of propane and butane which can be liquified. It has been shown that the natural gas from these fields is enough to supply domestic requirements for the next 20 years. Gas from the Boomerang area can be developed only if a new market outlet for gas is found. Thus, the feasibility of the alternative uses for natural gas has to be compared with the incremental cost of producing these reserves.

Exploration Costs:

7.26 For the purpose of incremental costs, the relevant discovery cost is that of the future. A sound practice of the hydrocarbon industry is to replace each cubic foot of gas produced by discovering a new one. To estimate future costs, YPFB's five year exploratory program (1981-1985) was used. The program specified a total expenditure of US$325 million in 1980 prices.

7.27 Assuming that the reserves discovered during the 1981-85 period will be produced over the following 15 years, and that the opportunity

1/ This 1981 Plan assumed a gas price increase from US$1.55/MCF in 1982 to US$4.50/MCF in 1989 and thereafter. The reassessed Power Plan is based on a constant gas price of US$3.00/MCF.

cost of capital is currently 14%, the exploration cost can be computed at US$0.47/MCF 1/.

Development Costs

7.28 To estimate this category of costs for the Boomerang area, YPFB's development plan for 1981-85 was used. It includes detailed additional geophysical work, step out exploratory wells to define the limits of the fields and the various productive horizons, development drilling, investment in a gas/liquid separation plant, and basic gathering and transport pipelines. The result of the exercise is very much dependent on the rate at which gas is to be produced and the capital cost. Assuming the basic production schedule, the development cost can be estimated at US$0.45/MCF (Annex 1.35).

7.29 It has been indicated (para 3.10) that it is technically possible to accelerate production of natural gas in condensate fields, beyond the optimum efficient level, if a substitute for natural gas is reinjected into the reservoirs. The production cost of nitrogen by cryogenic air separation techniques, is estimated at US$0.8 to US$1.2 per MCF, based on the United States experience for locations where field energy costs range between US$2-3/MMBtu.

Operating Costs

7.30 Operating costs are derived from YPFB's annual financial statements 2/ and estimated at US$0.11/MCF.

Transport Costs

7.31 Based alone on investments for the Altiplano pipelines and the foreseeable gas throughput, the transport cost for gas is estimated at US$1.20-2.00. YPFB should study the advantages in applying an uniform gas price throughout the country, distributing the regional transport cost to all gas users.

Summary of Incremental Gas Costs

7.32 The technical incremental cost of producing, gathering and transporting gas in Bolivia are estimated on Table 7.4:

1/ Annual recovery of investment is US$53 million. Average annual production is 1703.6 x 10^9 CFGE/15 years = 113.6 x 10^9 CFGE per year (Annex 7.5). It is evident that with accelerated production, this cost would decline. On the other hand, this cost will increase over time because of diminishing returns.

2/ In 1980, YPFB produced some 52 BCF of gas. US$5.9 million are operating costs. They exclude taxes, royalties, purchase of gas from private operations, interest payment and depreciation.

Table 7.4: Incremental Gas Costs
(US$/MCF)

	Boomerang	Condensate Fields
Exploration Costs	0.47	0.47
Development Costs	0.45	1.20 1/
Operational Costs	0.11	0.11
Sub-total	1.03	0.58-1.77
Transport Costs	1.12 - 1.97	1.12 - 1.97
Total	2.15 - 3.00	1.70 - 3.74

1/ Applies only if incremental volumes must be produced.

7.33 The so derived incremental production cost for natural gas currently being produced (US$0.58/MCF) is substantially higher than the accounting cost (US$0.18/MCF), calculated by YPFB for the first four months of 1982, which is based on past investments. Both values have to be affected by royalty and income tax, calculated in Bolivia on the basis of gross revenues. According to YPFB's estimate these amounted in 1982 to US$0.24/MCF. Thus, YPFB's supply cost is estimated at US$0.42/MCF, while its real economic cost is at least US$0.82 MCF. Finally, in the Table above, future average transport costs to the Altiplano region were estimated to range from US$1.12 to US$2.00/MCF. The added economic cost of US$1.94-2.79 compares to a present price of US$1.00/MCF. At this price, the investments required to supply the market in the future are not economic.

Fuel Oil/Gas Price Ratio

7.34 The GDC gas survey in Santa Cruz indicated that "the experience of industrial gas conversion had shown that there are no technical problems involved with the conversion and that the average cost for converting was $b5.75/MMBtu of fuel consumed annually. These costs varied from a low $b1/MMBtu to a high of approximately $b17.50/MMBtu. At the mid-1982 cost differential between fuel oil and natural gas ($b210.18/MMBtu vs $b42.85/MMBtu or a ratio of 4.9:1), this would mean that the average industrial consumer would recover the cost of conversion within 1.5 years, with a cost recovery range of 3 months to 4.5 years for the low and high cases."

Liquid Products' Price Structure

7.35 The present relative price structure in thermal equivalent terms is s shown in Table 7.5 below.

Table 7.5: Current Retail Prices in Energy Terms

	US$/MMBtu
Gasoline	5.43
Gasoline Regular	3.88
Kerosene	1.14
Diesel Oil	3.26
Fuel Oil	2.93
LPG Domestic Use	0.53
Industrial Use	1.49
Automobile	2.90

LPG Price:

7.36 The current price for LPG distinguishes between domestic, industrial and transport uses. Domestic LPG, which represents the bulk of sales, is currently priced below the production cost, estimated at US$2.30/bbl in 1982, 1/ and well below the full expensed supply cost considering the transport and distribution costs of LPG. Maintaining these prices in the future would mean jeopardizing future production plans. The strategy in the long term should aim at unifying these prices. In the short term, the price for domestic and industrial LPG should be equalled (to inhibit substitution, which leads to an increased distribution cost for YPFB) and raised to at least 50% of the opportunity cost.

Gasoline Prices

7.37 The large price differential between high octane and low octane gasoline is not justified on: (a) refinery costs nor (b) opportunity cost. In addition, about 60% of the vehicles operate at high altitudes, where the octane requirements are much less important. Therefore, the price of superior gasoline (low octane) should be increased and the distribution of high octane gasoline limited to the lowlands. This reduces refinery and distribution costs for gasoline.

Gasoline/Diesel Price Ratio

7.38 The policy of pricing diesel fuel below gasoline has induced substitution in the transport sector as indicated in Table 7.6 below. Given the domestic supply constraint of diesel, it is recommended

1/ For the first eight months of 1982, YPFB estimates the production cost of LPG at US$5.00/bbl from the refinery (26% of total) and at US$1.35/bbl the LPG produced at gas plants.

that the price for this product be elevated to the price level of gasoline in thermal equivalents.

Table 7.6: Fuel Use in Road Transport, 1975-81
(MTOE)

Fuel	1975	1976	1977	1978	1979	1980	1981
Gasoline	296	313	338	356	368	374	375
Diesel	54	63	98	130	134	147	150
LPG						0	4
Total	350	376	436	486	502	521	529

Prices (US¢/gal.)

	Prior to Nov. '75	Dec. '75 Nov. '79	Dec. '79 Dec. '80	Jan. '81 Jan. '82	Feb. '82	Nov. 82
Gasoline Premium	N.A.	94.6	90.8	106.0	86.0	66.0
Gasoline Superior	20.8	66.2	75.7	90.8	68.6	47.3
Diesel Oil	10.4	24.6	60.5	90.8	68.8	43.5
LPG	N.A.	N.A.		45.4	43.0	15.6

LPG/Kerosene Price Ratio

7.39 The present ratio between the prices of these fuels is adequate to induce residential consumers to continue substituting by LPG, as the supply of this fuel increases. However, the large difference between these two domestic fuels and industrial diesel and fuel oil will lead to uncontrollable substitution and in the end will defeat the social objective pursued with this pricing policy. Furthermore, it is suggested to consider replacing kerosene by gasoline for rural household uses. This can only be achieved if kerosene and consequently LPG prices be increased in parity with gasoline.

Table 7.7: Residential/Commercial Sector
(MTOE)

	1975	1976	1977	1978	1979	1980	1981
Kerosene	134	117	108	99	98	90	62
LPG	34	43	56	69	84	115	140

Prices (US¢/gal.)

	Prior to Nov. '75	Dec. '75 Nov. '79	Dec. '79 Dec. '80	Jan. '81 Jan. '82	Feb. '82	Nov. '82
Kerosene	4.7	5.7	15.1	60.6	43.0	15.1
LPG	N.A.	4.6	14.8	24.5	16.3	5.2

Source: YPFB and Staff estimates.

C. INSTITUTIONS

7.40 The Ministry of Energy and Hydrocarbons (MEH) is responsible for formulating energy policies and for regulating the exploration, exploitation, industrialization and utilization of all energy resources, except forestry which is under the responsibility of the Ministry of Agriculture.

7.41 In principle, the MEH carries out its regulating functions for the hydrocarbon sector through the Direccion Nacional de Hidrocarburos and has under its jurisdiction the oil and gas corporation Yacimientos Petroliferos Fiscales Bolivianos. The electric sector is regulated by the other department of MEH, the Direccion Nacional de Electricidad (DINE). The National Power Company (ENDE) as well as the Rural Electrification Institute (INER) are also under the jurisdiction of this Ministry.

7.42 MEH is insufficiently equipped to exercise its functions and to coordinate the efforts necessary to successfully meet Bolivia's future energy needs. It is suggested that a strong and capable energy planning department be created within this Ministry. 1/ This unit must be staffed with highly qualified personnel, equipped with analytical tools, and advised by outside experts during its initial years. Free flow of information to and from the energy companies and with the other ministries of the economic cabinet must be established. This Department working together with strengthened Hydrocarbon and Electricity Divisions, would be in charge of proposing and evaluating energy strategies, scheduling programs and monitoring those that are implemented. It would also make sure that a proper link is established between economic objectives and energy, and would coordinate with the Ministry of Agriculture in order to develop programs intended to increase the rural population's standard of living, including energy supply.

7.43 The Bolivian population must be made aware of the profound changes in energy demand structure that are necessary to ensure future economic growth. Therefore, the Government through MEH will have to lead a public campaign to explain its strategy and obtain the population's support. The conversion and conservation objectives must be brought about by a two-pronged approach: (a) technical assistance and credit lines for project evaluation and implementation; and (b) legal enforcement.

7.44 The organization and management of the energy corporation has been analyzed in former Bank reports and specific programs to strengthen these institutions are underway. In the following only those recommendations that are related to specific issues dealt with in this report will be discussed.

1/ In early 1983, an initial Planning group was set up, sponsored by OLADE-EEC.

Hydrocarbons

7.45 The Bolivian Government will have to revise its policy regarding private participation in the sector. This report has highlighted the dramatic efforts needed to meet domestic demand. Furthermore, in the event of an agreement on the large export project to Brazil, production of gas will almost double. As a result, exploration will have to be promoted, new fields developed and investments in surface handling equipment made. This requires a large increase in professional and managerial capability and financial resources. It is not certain whether YPFB will be able to face these challenges alone and build-up its institutional capability in the short time within which these efforts must be made (about five years).

7.46 However, the mission considers that the present legal framework is not the most favorable to the Bolivian interests nor to the potential private participants. Currently, Bolivia's general Hydrocarbon Law postulates private participation in exploration, development and production of hydrocarbons under production sharing contracts. Also the law authorizes YPFB to agree on sole risk contracts for exploration alone (Article 51). The general Hydrocarbon Law does not define the production sharing percentages nor the production distribution systems. It is YPFB's responsibility to agree on these terms with each individual contractor and for each acreage. Furthermore, the law establishes that YPFB shall retain the volumes necessary to pay for the contractor's national and departmental tax liabilities. These volumes are valued at the well head price. In the present contracts, company/government splits are 40/60 or 50/50 of gross production. Taxes 1/ are paid by YPFB on the total volume produced. The companies' tax liability is fully met out of the Government's share of production.

7.47 The manner in which the general Hydrocarbon Law is being applied has several shortcomings: (a) the rigidity of the sharing arrangement deters exploration for marginal fields while obtaining for the Bolivian Government too small a profit share of large discoveries; (b) because the contractor's income tax is paid by YPFB, there are considerable doubts about whether US companies are able to obtain a foreign tax credit for Bolivian income tax liabilities; (c) because the law limits private participation to exploration, development and production, YPFB has the obligation to enter into all other peripheral activities (transport, refining, marketing). This distracts the limited technical and financial resources of the national oil company, when it should concentrate them on those objectives with the highest financial and economic returns.

7.48 The mission, therefore, recommends that the Government revise its general Hydrocarbons Law and/or the regulations that norms its

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1/ There are two main taxes: (a) a 11% royalty paid to regional departments, and (b) a 19% income tax to the National Treasury. Both are based on international values of crude oil, minus deductions for processing and transporting costs as well as own consumption.

application and the tax laws. It should obtain the advice of legal and economic specialists on the current features of international contract formulas, including new contractual approaches to facilitate greater participation of private oil companies such as secondary recovery contracts in YPFB's acreage, "exploration only" contracts, service contracts and joint venture contracts, and design a new model contract.

7.49 Some Bolivians consider that the production sharing agreements should only be contracted for high risk ventures, in geologically less known or geographically removed zones, and that the best prospective areas should remain reserved for YPFB's activities. Undoubtedly, this opinion stems from the desire to use natural resources to the fullest for the country's economic development. However, it does not take into account that the sooner the resource is being produced, the derived revenues can be reinvested in the economy. At present, the financial limitations do not permit YPFB to develop the hydrocarbon potential at the rate necessary to backup the economic recovery process and to lead the country into a phase of steady growth. The economic reasoning therefore induces to consider capturing foreign investments for the development of Bolivia's hydrocarbon resources. A possible strategy could be to invite private operators to enter into agreement to explore high risk prospects, such as for stratigraphic traps, being compensated with a share in an area reserved for YPFB. Another alternative would be to offer the private participant a share in the gas export market 1/ in proportion to the reserves of gas discovered. It would also be desirable to investigate ways of involving private companies as service contractors on YPFB's acreage, establishing a fee payment for actual results.

7.50 Efficient management of the sector will provide guarantee that the resources are optimally exploited. The institutions must be capable of formulating and executing clearly defined and well coordinated programs and projects. The Ministry of Energy and Hydrocarbons must assume its role, defining an objective energy policy and supervising the operating companies. The mission recommends:

(a) support for the Planning Division (Direccion de Planeamiento) as the unit in charge of formulating and evaluating energy strategies; and

(b) staffing the Hydrocarbons Division (Direccion Nacional de Hidrocarburos) with qualified and independent personnel, as the unit in charge of reviewing the operations of YPFB and of private companies.

7.51 The loss of experienced professional staff in YPFB, the inadequate delegation of authority and accountability and the lack of

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1/ Tesoro and Occidental were given a share in the export market of Argentina (a total of 80 MMCFD) and in the new contracts currently under discussions, the operator is guaranteed a 50 MMCFD share in the Brazilian market, should this project become a reality.

coordination between operative and financial objectives, hinder the performance of the company. The mission recommends the following specific measures to strengthen the institution:

(a) Definition of the specific functions of each managerial and technical department, setting objectives, evaluating staffing requirements and establishing control systems to insure that objectives are met.

(b) Revision of the salary structure, to directly relate remuneration to the level of responsibility and productivity, and indirectly to the salary levels in the private sector, within and outside of Bolivia.

(c) Formulation of a career development program for professionals in technical and managerial positions, taking into account the long term staff requirement of YPFB.

(d) Introduction of new administrative and financial control systems and revision of existing systems, in order to provide management with up-to-date and continuous information on stocks, on input and output flows and on financial transactions.

(e) Implementation of analytical models that facilitate evaluation and planning of future activities and permit to optimize current operations.

(f) Hiring a productivity expert, on a fixed term contract, with sufficient authority to promote performance and to reduce costs.

7.52 Furthermore, the company should incorporate into its scope of responsibilities the promotion of demand management and energy conservation. A specific user-oriented advisory group should be created, which would operate in close coordination with the marketing departments. It would assist consumers in implementing projects leading to higher fuel-use efficiency and to substitution from scarce to abundant energy forms. Furthermore, YPFB has to be given authority to monitor and enforce these programs.

Power Sector

7.53 A preliminary review of the power sector of Bolivia 1/ indicates the need for a major study of the legislation, organization, financing and operations of the entities involved in the power sector. The mission recommends that this study be executed at the earliest.

1/ "Report on the Study of the Power Sector of Bolivia," by Simons Resource Consultants, Canada 1982, financed by UNDP.

7.54 From the organizational and legal point of view, the mission shares the preliminary review's recommendations that the National Electrical code be updated and that DINE be given more independence to act and to make decisions on tariff recommendations. Similarly, that ENDE be restructured both as to its Board of Directors and its management to facilitate delegation of authority and decision making.

7.55 The Bolivian Government announced in November 1982 the decision to Nationalize the Bolivian Power Company, which has served the market of La Paz under a longstanding concessionary agreement. This will give ENDE an expanded financial base and the possibility of planning the expansion of its system on a larger and sounder basis, but also calls for stengthening of ENDE's technical system and long term economic and financial planning capability.

Rural Electricity and Small Scale Renewables

7.56 INER was created for the purpose of introducing electricity in small towns and villages. It established power supply (mainly diesel based) in about 50 rural centers, where INER formed cooperatives to generate electricity and collect revenue based on tariffs designed to cover costs. Many of these have failed due to inability to operate, maintain and administer the plants. The mission recommends that the management of current operations as well as future decisions relating to new investments should be reviewed in the context of a comprehensive rural electricity plan.

7.57 INER has attempted to expand its program into alternative energy sources, investigating the applications of solar, wind, biogas and small hydro. However, this organization does not have the staff, technical skills or funds to carry out effectively such a dissemination program. The mission suggests that an alternative institutional arrangement be sought to execute the rural electrification program.

Recommendations

Pricing

(a) The Bolivian Government should adopt the concept of opportunity costs as the pricing principle for all energy products and increase prices to that level as soon as possible.

(b) The prices for petroleum products should be pegged to the dollar and increased gradually and periodically at a rate higher than internal inflation.

(c) The relative price structure of petroleum products should reflect the constraints on domestic supply. Fuel oil and diesel prices should be increased at the level of gasoline prices in energy equivalent terms. Simultaneously, kerosene and LPG for domestic use should be increased at the same level, to avoid interfuel substitution in the industrial sector.

(d) The price of natural gas should be raised to US$2.00/MCF in the short run, and to its true economic cost in the longer term.

(e) Similarly, power rates should be adjusted gradually towards its long run marginal cost level, by periodic increases at a rate higher than internal inflation.

(f) There is a need to make a national tariff study to rationalize the differences in the tariffs applied by the regional distribution companies, both in terms of the level of energy and demand charges and of their structure.

Institutions

(g) Insuring the objectivity of the Ministry of Energy and Hydrocarbons, backing of the small global planning unit and strengthening the capability of the Hydrocarbon and Electric Divisions.

(h) Carrying out a public campaign to alert the public on the energy situation and to ensure cooperation for implementing the conservation and conversion strategy.

(i) Reorganizing the management structure of both energy corporations to facilitate delegation of authority and decision making and improving coordination.

(j) Revision of the hydrocarbon and/or its regulations and the tax laws, in order to incorporate current features of international contract formula, including new contractual approaches to facilitate greater participation of private oil companies.

VIII. SURPLUS GAS UTILIZATION

8.01 Surplus gas is defined as the volume difference between recoverable reserves and existing commitments. This chapter attempts to quantify this surplus and to estimate returns that could be expected if this gas were directly exported or converted into fertilizers or liquid fuels.

8.02 In Chapter 2, a long term projection to year 2010 of maximum gas demand was made. The estimated internal gas requirements (2.7 TCF over 30 years) exclude the inputs of natural gas into the large industrial complex envisaged for the Mutun area (export oriented steel mill and chemical plants). To insure that this quantity of gas is available in the future when such projects become economically feasible, it is necessary to make adequate choices at an early date. The obvious consequence of entering into an additional export commitment is that electric power requirements will have to be generated from hydro, geothermal or other sources. Such a decision would free some 0.8 TCF of gas, or 30% of total internal requirements, for other uses. The incremental capital cost associated with the hydropower option is a real cost that should be recovered through the gas export price (para 8.11).

8.03 At present, Bolivia has only one export commitment. It supplies 200-220 MMCFD of gas to Argentina on a contract that expires at the end of 1991 1/. Because of political considerations, it can be expected that Argentina will continue to purchase gas at the end of the contract, in spite of its own substantial gas resources.

1/ This is a take-or-pay type contract, with some flexibility in terms of periodic offtakes. The base price is revised every quarter and was US US$4.27/MMBtu in early 1982. Argentina also purchases additional amounts of heavier hydrocarbons contained in the gas flow at a price equivalent to Arabian Gulf spot market prices for LPG and natural gasoline.

Table 8.1: Gas Surplus Estimate
(10^9CF)

	1982-2000	1982-2010
Gas Resources (Proven and Probable Reserves)	6,700	
Internal Commitments		
Direct use as fuel (final demand)	383	1386
Power generation	315	809
LPG extraction	106	169
Fuel losses and consumption in hydrocarbon industry (10% of production)	160	320
Total Internal Commitments	964	2684
Export to Argentina		
to 1991	800	800
(or to year 2001)	(1600)	(1600)
Total Commitments	1764 (2564)	3484 (4284)
Gas Surplus	4936 (4136)	3216 (2416)
Gas requirement for the export project to Brazil over 20 years	2,920	

1/ Based on exports to Argentina until 1991.

Source: Mission estimate.

Export Project to Brazil

8.04 In October 1978, Bolivia signed with Brazil a letter of intent for the supply of 400 MMCFD of gas to the Sao Paulo area. The contract negotiations are now underway. The agreement is conditional on:

(a) Certification of Reserves: can Bolivia certify and set aside an amount of natural gas reserves sufficient to supply the contract over 20 years?

(b) Purchase price: can the parties agree on a price for gas which is economic for the purchaser and attractive to the seller?

8.05 Reserves: Table 8.1 clearly illustrates the importance of this condition. The contract's aggregated commitment over 20 years is equal to 2,900 x 10^9CF, which are precariously in balance with the surplus calculated over 30 years. The balance is further endangered by the uncertainty relating to the reserve base. To lift some of these doubts, YPFB has initiated, with assistance from IDB/IBRD, an exploratory program of the gas fields in the Boomerang area and Vuelta Grande. The program is successfully underway and it is hoped that it will reach its objective by March 1983. Furthermore, YPFB will shortly contract a reserve certification program for its proven reserves classed in groups I, II and III. This program will include the following fields: Santa Rose, Yapacani, Enconada, Palometas, San Roque, Naranjillos, Vuelta Grande, Colpa and Rio Grande. However, it has to be noted that these programs will not add to the amount of 6.7 TCF used in Table 8.1, but simply provide a greater certainty to that number.

Price

8.06 The letter of intent defined the parameters for price negotiations. It was agreed that the price basis would be the international price of these liquid fuels which are to be replaced by natural gas in Sao Paulo. The border price was defined as the difference between the base price and the average cost of transportation from Sao Paulo to the Bolivian border.

8.07 The price basis chosen does not have a single meaning. An international price can be defined in at least three ways:

(a) the price of the liquid fuel at the refinery gate of a major exporting center (such as the Caribbean), plus freight and related expenses to Sao Paulo;

(b) the price at which Brazil would be able to sell its fuel surplus in international markets. This implies a net back calculation of refinery price at a major exporting center (Caribbean), less the transport cost from Sao Paulo to the refinery center;

(c) the price to the final consumer of the liquid being replaced which is derived from imported oil.

8.08 From the point of view of Bolivia, the price of gas must generate sufficient revenue to cover all gas supply related expenditures, must provide a compensation for the switch to hydropower generation and for the depletion of the national resource.

8.09 A recently concluded basic engineering study of the Santa Cruz-Sao Paulo pipeline provides a good basis for estimating the transport cost. The study arrives at a technical investment figure for the line of US$1,184 million in 1982 prices, which if escalated to completion (1986) would increase to US$1,695 million. The average unit transport cost to pay for this investment, plus operational expenses, is estimated at US$1.99/MCF, separated into: (a) US$0.62/MCF for the Bolivian portion 1/ and (b) US$1.37/MCF for the Brazilian transport from Corumba to Sao Paulo.

8.10 Furthermore, the export project implies that Bolivia will incur in investment expenditures to develop the already discovered gas fields, in new exploration costs to replenish the resource base, in transport costs from the fields to the export pipeline, and in additional operational costs. The sum of these cost elements has been estimated (Table 7.4) at US$1.03/MCF.

8.11 Compensation for the switch to hydropower generation can be calculated as the result of dividing incremental capital costs by the gas export volume, both elements discounted at an appropriate rate. This compensation is estimated at about US$0.94/MCF 2/ if both flows are uniformly distributed over time and discounted at the same rate.

8.12 The addition of these cost elements (para 8.09-8.11) permits to arrive at a minimum border price of US$2.59/MCF. This figure does not include compensation for the depletion of Bolivia's natural resources in the form of royalty or taxes.

8.13 Given the magnitude of the investment (about US$800 million in current prices for Bolivia in the transport pipeline and in the development of the gas fields), the important policy implications of the projected pipeline and the wide price range within which the decision can be taken, the mission recommends that the Government obtains expert advice from professionals that have a good understanding of the international as well as Brazilian-Bolivian economic and energy issues. The present negotiating climate is particularly difficult because of the world economic stagnation, the softness of the oil market and the doubts regarding the extent to which the energy market should and will be restructured during the next decade or two.

8.14 To assist the Government in this endeavor, the following sections discuss: (a) the terms of reference of selected international gas export contracts; (b) the Brazilian energy situation; and (c) the alternative uses of gas as input into chemical plants and gas conversion into liquid fuels.

1/ The average transport cost for the Bolivian section assumes for early 1990's an increase in the throughput from 400 to 520 MMCFD to supply the gas requirements in the Mutun area. Should these industrial projects be delayed, the transport cost could be slightly higher.

2/ Power expansion requirements are estimated to increase from 406 MW in 1981 to 719 by 1990, to 1336 MW by 2000, and to 2304 MW by 2010. Total capacity addition is 1898 MW over the period. Incremental capital cost is calculated as the difference between US$2000/kW for hydro and $550/kW for gas-based units. Total export sales are 2.920 TCF over 20 years at a regular flow of 400 MMCFD.

A. International Gas Export Contracts

8.15 There are currently a number of gas export contracts in force and many of these have been revised in the recent past. Table 8.4 gives a sample of the terms of these contracts in reference to the choice of base price and escalation factors. The conclusions that can be drawn from these examples are discussed on the next page.

8.16 Base price: Gas is a clean-burning and versatile fuel; in addition it has characteristics of its own that give it a value above the thermal equivalent as, for example, in glass manufacture and petrochemicals. Table 8.2 illustrates that base prices are currently in the US $4.25-6.36/MM Btu c.i.f. range. 1/ A few contracts are based on a f.o.b price, such as Algerian contracts with France and Belgium; a few others specify border prices.

1/ This is equivalent to a price for a barrel of fuel oil of US $24-30, assuming a transport cost that varies between US¢25 and $2.00/MCF.

Table 8.2: Base Price and Escalation Factors in International Gas Trade

Importer	Exporter	PRESENT WORLD GAS PRICES ($/MMBtu) VOL (bcm/y)	FOB	CIF 1/	AS OF	INDEXATION TERMS PERIOD	ALPHA FACTOR	INDEX	HOW APPLIED
U.S.	CANADA	28.3	-	4.94 2/	1.82	Irreg.	1.00	Crude imports to Toronto/US Alt. Fuels Price	
U.S./BORDER GAS	MEX/PEMEX	3.1	-	4.63 3/	1.82	Qtrly.	1.00	20:80 ratio of No.2 and No.6 fuels in major U.S. cities	% Change
FRANCE/GAZ DE FRANCE	ALG/SONATRACH	9.1	5.12 2/ 4/		2.82	Qtrly.		Eight crude oils	Absolute Btu Equiv.
BELGIUM/DISTRIGAZ 5/	ALG/SONATRACH	2.5 6/	5.12 2/ 7/		1.82		.50 .50	Crude Exported by LNG producers Crudes Imported by Belgium	Absolute Btu equiv.
U.S./DISTRIGAS	ALG/SONATRACH	1.4		5.82 2/	1.82	1/2 yrly.	.5/.5	Prices of No. 2/No. 6 oil in NYH	% Change
U.S./TRUNKLINE 1/ 5/	ALG/SONATRACH	4.5	3.94		1.82	1/2 yrly.	.5/.5	Prices of No. 2/No. 6 oil in NYH	% Change
GERMANY	NETH/GASUNIE	23.9		4.45	10.81)		.95	LSFO (1%) with 5 Month Lag	
GERMANY	NORWAY 8/	9.7		4.25	7.81)				
GERMANY	USSR 9/	11.0				Yearly	.96	.64 LSFO, .22 heating oil .10 wage developments	
GERMANY	USSR/Yamal	10.5	4.65 2/	4.65 10/	7.81		1.00	20% crude oil, 40% gasoil, 40% LSFO	% change
JAPAN	ABU DHABI	3.0	- 2/	6.36	11.81				
JAPAN/JILCOGP (Osaka Gas, Kyushu Elec. Chubu Elec, Kansa, Elec. Nippon Steel)	INDO/BADAK	10.5		5.93 2/	11.81			Oils imported by Japan.	
JAPAN	BRUNEI	7.5		5.77 2/	11.81				
JAPAN	US/ALASKA	1.5		5.86 2/	11.81				

1/ For LNG projects, approximately 40¢/MMBtu should be added for regasification costs, except for Trunkline/Algeria and U.S. Distrigas/Algeria which include regasification.
2/ Basis of Contract.
3/ To achieve parity with Canada.
4/ 13.5% of the fob price will be paid by the French Government.
5/ Not in operation.
6/ From 1982-85. At that time, price is renegotiable and volume increases to 5 bcm.
7/ Due to "favoured nation" clause, actual contract price will depend on outcome of Algerian negotiations with France, Spain and Italy.
8/ Does not include Statfjord gas.
9/ Does not include proposed additional gas through the proposed Soviet (formerly "Yamal") pipeline.
10/ Contracts are denominated in importing country currency and contain a floor price of about $5.40/MMBtu.

Source: IEA - Natural Gas - Prospects to 2000.

8.17 The base price reflects the lower thermal equivalent value in markets where gas has to compete with other fuels for the industrial and electricity generation markets. This appears to be the case of Sao Paulo, because of the economies of scale of the pipeline project and because reaching the residential/commercial sector, implies high distribution costs (low volume use and great seasonal variance).

8.18 In countries where there are severe restrictions on SOx and NOx emissions, users are prepared to pay a premium of about US$1.0-1.50 MMBtu, as the comparison between Japanese and European contract prices illustrates. Sao Paulo has a severe pollution problem. The use of natural gas would substantially reduce the cost of the antipollution measures. 1/

8.19 The absolute level of the base price has increased substantially in recent years. The parity with liquid fuels is fixed, depending on the negotiators' perception of factors such as energy scarcity and security of supply. For example, the export price of gas from Holland to neighboring countries is set at a border base price of US$4.45/MMBtu. The border price for the Mexican-US gas trade is US$4.63/ MMBtu. The reference point in the case of the European contracts is the price of low sulphur fuel oil; in the Mexican-U.S. deal, the gas price was calculated using a 20:80 ratio of the average prices of No. 2 (heating) oil and No. 6 (fuel) oil in a representative sampling of United States cities.

8.20 The indexation clauses of gas contracts contain the following elements:

(a) Period: the interval at which indexation is applied varies from three to six months; the shorter the period the better for the seller as the reference period is usually chosen as the previous interval for the indexation.

(b) The alpha factor: refers to the portion of the base price which is affected by the index change. It generally is 1.0.

(c) Index: Currently the contracts tie the gas price changes to the variation in crude oil or petroleum product prices. It is important to choose an oil reference price over which none of the trade partners have control. Thus the average price of crude imports into Brazil should not be an acceptable index to Bolivia. Also some contracts have currency adjustment clauses, which can be important if the two partners have very dissimilar foreign trade structures.

(d) Application of index: This refers to whether the index is applied as an absolute amount or as a percentage change.

1/ IBRD has granted a loan to Sao Paulo for pollution control.

This is especially important when the base price of gas is lower than the thermal equivalent of the index elements at the time the contract takes effect.

(e) Most favored nation clause has been included in some cases. This should be of interest to Bolivia in case Brazil and Argentina enter into a gas trade agreement in the future.

8.21 As the letter of intent does not provide clarity regarding the liquid fuel that will be replaced by natural gas, nor establish a mechanism of indexation, the mission recommends that in the contract a formula be built in that would raise the base price from the fuel oil reference to diesel or to the barrel of crude oil. Similarly, the indexation should be referenced to a basket of products or crude oils, to increase its stability.

8.22 Furthermore, given the magnitude of the investment in the development of gas production and in the pipeline, Bolivia should also set a floor price in case the indexation goes negative and introduce a take-or-pay clause to guarantee sufficient revenues to cover investments.

8.23 Finally, this negotiation could serve as an example for intensifying trade among developing countries. Therefore, the parties should put their best endeavors to facilitate joint venture projects as set out in the initial letter of intent, especially for a fertilizer and a methanol plant.

8.24 Bolivia is under great pressure to increase foreign exchange earnings to pay back the external debt and to finance essential imports. The gas export contract to Brazil would mean an increase in future export capability and therefore enhance the Government's position in renegotiating debt and obtaining new capital outflows to bridge the current gap. Bolivia's negotiating team is therefore induced to reach an agreement as soon as possible. The Brazilian team, on the contrary, has no immediate reason for wanting to come to the end of negotiations.

B. Brazil's Energy Situation

8.25 Brazil is making a major effort to restructure its energy market and reduce the country's dependence on imported oil. The program calls for a total reduction of oil imports from 1,700 MBD by 1985 under the business-as-usual-scenario to 1,150 MBD. This is to result from the following measures: increased domestic oil production 250 MB/D; interfuel substitution 350 MB/D; and conservation 200 MB/D. The substitution and conservation programs will affect in different degrees the demand for individual petroleum products. For example, it is estimated 1/ that the share of fuel oil in total demand will decrease from 30% in 1978 to 22% by 1985. In a similar manner, gasoline will decrease its share from 23%

1/ Brazil: Energy Assessment Report, IBRD -1982.

to 14% during the projection period. The fuels with growing shares are diesel, LPG and Naphtha. This shift requires adjustment of the refining capacity. Table 8.3 shows that without such an adjustment the surplus of fuel oil would at least be equivalent to 70 MBD.

Table 8.3: Brazil: Possible Supply/Demand Refinery Balance in 1985 1/
('000 bbls/day)

Product	Supply	Demand	Surplus/(Deficit)
Gasoline	145	162	- 17
Diesel Oil	364	384	- 20
Fuel Oil	319	248	71
LPG	72	120	- 48
Naphta	90	107	- 17
Others 2/	114	135	- 21
Total Products	1,104	1,156	- 52

1/ Assumes that the 1985 crude oil slate is similar to that in 1978; that no further conversion capacity beyond that currently envisaged is added; and that there would be a desire to limit direct product exports.

2/ Others include kerosene, lubes, solvents, greases, paraffin and asphalt.

Source: Brazil Energy Assessment Report

8.26 The region around Sao Paulo is Brazil's most important industrial center as the fuel consumption figures show. In 1978, Sao Paulo consumed 125 MBD of fuel oil, or 40% of total sales in Brazil; industrial diesel consumption is estimated at about 25 MBD, or 33% of diesel sales in the region.

8.27 It is difficult to estimate the industrial fuel consumption of Sao Paulo by 1985-86 (about 150 MBD in 1978). It has been announced that 100% of ZESP's power system in Sao Paulo must substitute to coal (about 10 MMTY); and that by end of 1984 all fuel oil in cement, iron and steel plants must convert to coal. The industrial coal price in Sao Paulo is estimated at about US$30/ton or US$1.5/MM Btu for Rio Grande do Sul coal. This price is the result of heavy subsidization.

8.28 Brazil's oil products' prices are aligned to international levels, and carry a high excise tax. Fuel oils have a quality differential of about US$7/Bbl for sulphur; this is similar to world market differential of about US$1.60/MM Btu.

Table 8.4: Brazil - Fuel Prices - Retail Level as of July 1982 1/

	US$/unit	Unit	US$/MMBtu
LPG	0.14	lb.	4.98
Natural Gas	5.76	MCF	5.51
Gasoline Premium	2.79	Gallon	22.85
Gasohol	2.79	Gallon	
Diesel	1.67	Gallon	12.50
Motor Alcohol	1.63	Gallon	
Kerosene	1.70	Gallon	12.76
Fuel Oil No. 6			
High Sulfur	29.15	Barrel	4.89
Low Sulfur	36.14	Barrel	6.50
Bunker C.	25.74	Barrel	4.32

Source: Energy Detente, July 9, 1982
Exchange Rate Cr. 169.51 per US$1.00

8.29 Sao Paulo has currently no access to natural gas; a naphtha based town-gas system exists which serves a reduced number of industrial consumers. However, it is of interest to reproduce here the Brazilian gas price structure for the different types of consumers, which shows a subsidy for gas as a feedstock, and a penalty of 34% above the thermal equivalent of fuel oil, for its use as fuel.

Table 8.5: Brazil: Natural Gas Prices - October 1981 1/

Type of user	US$/MMBtu
Petrochemical Industry	2.87
Fertilizer	2.08
Steel Industry	2.27
Other Users (as a combustion fuel)	6.80

1/ Converted at the exchange rate of CR$115/US$1.

8.30 The brief review of the Brazilian and regional energy scene indicates that the proposed gas imports from Bolivia (400 MMCFD equivalent to 70 MBD of fuel oil) could be important. They will probably represent some 30% of total industrial oil consumption by 1985, which implies changes in the investment programs for refining and for coal production and transport. Private industry will also have to incur some expenditures to adapt to the new fuel.

8.31 From the point of view of price, the individual consumer will not be willing to pay more than the thermal equivalent for the fuel currently used less conversion costs. If the anti-pollution effort is serious, this replacement fuel is low-sulphur fuel oil.

C. Industrialization of Natural Gas

8.32 As an alternative for the pipeline to Brazil, the Bolivian authorities want to explore gas conversion technologies for producing fertilizers and/or liquid hydrocarbons to supply the domestic market and for export. None of these possible routes appear to be financially feasible at present. The domestic market is too small to provide a reasonable production scale, while the international market has a higher risk because of the excess supply likely to occur during the second half of this decade. Annex 3 provides the technical data on which the following conclusions on ammonia/urea, methanol, methanol-gasoline and gasoline-diesel are drawn.

Ammonia-Urea

8.33 The manufacture of ammonia-urea can in principle be attractive. On the average, the net back value for gas in this use is estimated at about US$3.0-3.5/MCF 1/ for a large export plant. The mission estimates, however, that the Bolivian project would have a negative return of US$1.50/MCF of gas used in the plant.

8.34 Bolivia's planning commission (CONEPLAN) approved in July 1981 the project for an ammonia-urea complex. In January 1982, YPFB contracted a basic engineering study for a 165 tons/day ammonia plant (Haldor Topsoe technology) that would produce 250 tons/day of urea and at a later date some 50 tons/day of ammonia nitrate. This plant would in practice require an input of 8 MMCF/d of natural gas. This capacity was selected on the basis of the optimum use of fertilizers for a fully developed agricultural sector in Bolivia. The plant would be built at a cost of US$85 MM (1980 dollars), close to the Palma Sola refinery in Santa Cruz. The financial analysis is based on a 70/30 debt/equity ratio and a world price for urea of US$260/ton. 2/ It was further assumed that surpluses would be marketed in Brazil at the international price less US$25/ton to account for transport to the Brazilian border.

8.35 It should also be noted that in the initial letter of intent (1978) signed between Bolivia and Brazil for the gas export project, it was agreed that a fertilizer plant for export to Brazil would be built as a joint venture in Bolivia. Since then, Brazil appears to have lost interest in such a joint venture.

1/ Bank's in-house estimate.
2/ IBRD estimate for 1990 concurs with this figure.

Market Considerations

(a) Domestic Market for Nitrogenous Fertilizers

8.36 Bolivia imports all its fertilizer requirements. Total imports for the agricultural year 1978/79 were 4,000 tons, of which 1,900 tons were nitrogenous fertilizers. 1/ This amount has practically not increased over the last 10 years. It is equal to applying 0.6 kgN/Ha of arable land and compares with an application considered adequate of 50-100 kgN/Ha. This is the lowest rate of nitrogen use in Latin America.

8.37 As in many developing countries, the structure of relative prices in Bolivia discriminates against agriculture, with the result that this sector has a low technology level and low productivity. For example, the average corn yield is only 1,370 kg./ha (or 18 bushels/acre). This compares with a world average of about 3,000 kg./Ha or an US average of about 100 bushels/acre. Current nitrogen consumption (1,900 tons of N equal to 4130 tons of urea) is only 5% of the proposed plant size (80,000 tons per year). Should the Bolivian Government commit itself to the full and accelerated development of agriculture it still would take at least 20 years to absorb the proposed capacity. 2/ It is evident that during the economic life of the plant, it will be mostly export-oriented.

(b) International Markets

8.38 Ammonia is a feedstock for fertilizers and for chemicals (synthetic fibres, resins, etc.). Major additions to productive capacity have initiated operations or are scheduled to come on stream in USSR, Mexico, Trinidad, Middle East, Canada, etc. This development will induce competition and pressure on ammonia prices, (and in effect on all nitrogenous fertilizers) and force suppliers to take full benefit of the economies of scale at the production and shipping level.

8.39 A recent market study 3/ estimates world-wide demand growth for ammonia over the 1980-2000 period at an average of 4.1% per year, increasing from 69 million tons of nitrogen (MMTN) to 155 MMTN.

8.40 Bolivia's first choice of export markets consists of neighboring countries. It is estimated that the Latin American regions' supply-demand balance for ammonia will improve during the period. Mexico, Brazil, Venezuela, Chile, Trinidad and Argentina have plans to increase capacity. Thus, despite the projected growth of 6.8%/year in demand, the total deficit for the region is likely to decrease from 1.1 MMTN in 1980 to 0.5 MMTN by 1990. Brazil, Argentina and Peru are likely to have a deficit position in nitrogen trade whereas Chile will have a surplus.

1/ FAO Fertilizer Yearbook - 1979. Figures refer to metric tons of nutrients : N, P_2O_5, and K_2O.

2/ In Burma, such an effort was made. During the last 15 years, fertilizer consumption increased at 17% p.a., from 8 to 86 MT in the period 1964-1979.

3/ Chem System Inc. & Davy McKee, Petrochemical Plan for Thailand, March 1982.

Table 8.6: Supply/Demand Balance for Nitrogen Fertilizers
(MTN)

Country		1980	1985	1990	1995	2000
Brazil	Demand	800	1500	2100	2600	3130
	Supply	290	850	1300	1700	2230
	Trade	(510)	(650)	(800)	(900)	(900)
Argentina	Demand	60	120	200	280	350
	Supply	45	70	80	300	300
	Trade	(15)	(50)	(120)	(20)	(50)
Chile	Demand	50	110	180	250	300
	Supply	90	120	450	450	450
	Trade	40	10	270	200	150
Peru	Demand	100	150	200	250	300
	Supply	70	70	270	270	300
	Trade	(30)	(80)	70	20	-

Source: Chem Systems Inc., Davy McKee - Market Studies - March 1982.
Revisions by Mission.

8.41 According to these figures, Brazil is by far the most interesting potential buyer. That country's deficit of ammonia as fertilizer feedstock is likely to rise from 0.5 MMTN to 0.8 MMTN between 1980-1990. In addition, Brazil's market for industrial ammonia is expected to grow at 7%/year from 0.1 MMTN in 1980 to 0.5 MMTN by 2000. To penetrate that market, Bolivia would have to be competitive not only with urea produced from domestic feedstock but with nitrogenous fertilizers (such as ammonia nitrate) derived from imported ammonia. Brazil's fertilizer industry is controlled by PETROFERTIL, a subsidiary of Petrobras, which should be contacted by Bolivia to explore further a possible joint venture. This company has recently started up a large ammonia/urea complex at Araucaria (1200 ton/day ammonia) based upon partial oxidation of heavy residuum asphalt which is a more complex and more expensive route. Two additional natural gas-based complexes are under construction.

8.42 International urea prices are expected to increase only moderately because of the likely surplus in world market. However, as illustrated in Table 8.7, expert opinions differ substantially.

Table 8.7: Urea Export Prices

	(US$/metric ton) Current Prices 1/	2/	(US$/Metric Ton) Constant 1981 Prices 2/
1981	230-250	216	216
1985	320-350	270	213
1990	610-620	450	265

1/ Obtained from the study by Chemsystem Inc.

2/ IBRD - Commodities and export projections - June 1982.

(c) Production Costs

8.43 The scale of the plant is very significant in production economics. A world scale complex (1,000 ton/day of ammonia and 1,700 ton/day urea) would cost about US$300-450 million and the unit investment cost would be about US$600-900/ton/year of urea. A plant of the size proposed for Bolivia could have an investment cost as high as US$1,200/ton/year of urea.

8.44 The financial evaluation of the Bolivian ammonia-urea project (Annex 3.2) would result in a production cost of about US$340/ton, well above the cost of importing urea from world markets. This calculation was arrived at assuming a 10% discount rate and zero value for gas. Thus, should the project be implemented, Bolivia would have to absorb a net loss of US$1.53/MCF of gas put into the plant.

8.45 In light of these figures, it is suggested that Bolivia insist in its gas negotiations with Brazil on a joint venture to build a world size fertilizer plant. If the gas pipeline to Brazil is built, it might be profitable for both parties to locate the ammonia-urea plant near the largest market, because it is cheaper to transport natural gas than to transport liquid, refrigerated ammonia or solid urea. The financial evaluation indicates that such a plant would provide Bolivia with a net return of US$1.50/MCF of gas.

8.46 The mission shares the Bolivian Government's concern to increase agricultural output and to supply fertilizers at a reasonable price. It is suggested that Bolivia improve urea marketing practices, to reduce the cost of fertilizer to the final consumer.

Synthetic Fuels: Conversion of Gas to Liquids

8.47 The Bolivian hydrocarbon industry has been considering the Fischer-Tropsch route, modified by SASOL in the Republic of South Africa, and the methanol-to-gasoline (MTG) route worked out by Mobil Oil Company as alternatives for using surplus gas. The preliminary economic evaluation prepared by professionals of YPFB 1/ was reviewed by Bank staff. In general, it was found that the costs associated with these projects are much higher than the estimates used in the Bolivian study. Because these routes lead to the production of synthetic fuels and use energy in the conversion process, the netback value for gas that can be expected to be achieved is considerably lower than the value of gas in direct use as a fuel. Among these alternatives the manufacture of methanol seems to be the most interesting and therefore should be studied in greater detail.

Mobil's Methanol-to-Gasoline Process

8.48 In January 1982, the New Zealand Government signed the final agreement with Mobil to build a synthetic gasoline plant using natural gas. The cost of the plant is now estimated at US$1.2 billion, an upward revision from US$500 million quoted in the initial project agreement in April 1980. The plant will have a nominal plant capacity of 570 MT/year of synthetic gasoline (or about 15,000 B/SD). These figures contrast with YPFB's assumptions of an investment of US$570 million and a capacity of 20,000 B/SD. According to YPFB, the gasoline plant would require input of 6,320 T/SD of methanol or the equivalent of four trains of 1580 T/SD each and total gas requirements would amount to 174.2 MMCF/D.

8.49 It must be emphasized that the New Zealand plant is the first commercial size plant of this type being built. The results of this venture are of interest to many countries in which security of supply, or high transport costs (in landlocked countries) are determining factors. It is still too early to estimate a cost per barrel of gasoline produced. Synthetic gasoline will probably not be competitive with imported oil and as an export alternative for gas, this route will provide a lower netback value than the methanol route. Given Bolivia's high opportunity cost of capital at this time, the mission suggests that further consideration of this route be postponed.

Methanol 2/

8.50 New chemical applications and the perspective of methanol use as a synthetic fuel have renewed the interest in this basic product and have opened new market opportunities for natural gas. However, it is the mission's opinion that these developments will be slow unless dramatic events create an interruption in the world oil supply.

(a) Domestic Market

8.51 In terms of Bolivia's internal market, methanol could immediately be used as a gasoline extender, high-octane additive, (106-116 RON) in low-level methanol/gasoline blends (up to 5%). Such a use does not require any engine refitting or replacement of parts in the

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1/ Evaluacion tecnico-economica preliminar - Proyecto Conversion Gas Natural en Hidrocarburos Liquidos - Juno 1981. By Ing. D. Pozo, J. Barrientos & Lic. M. Camacho.

2/ Much of the material is extracted from: "Emerging Energy and Chemical Applications of Methanol: Opportunities for Developing Countries", World Bank, April 1982.

vehicle fleet nor any modifications in the existing gasoline distribution system. This market would be equivalent to 500-700 barrels per day (60-90 tons/day).

8.52 The use of higher-level blends or of straight use of methanol in spark-ignition engines and in diesel engines can only be considered in Bolivia once the international automobile industry brings forward engines modified or redesigned to the characteristics of this fuel. It is not economic to custom-retrofit cars in Bolivia.

8.53 Given the shortage of liquid fuels and in particular of heavier distillates in the domestic market, methanol could become an industrial and household fuel in areas where gas pipelines are not economic. Because methanol use would require some modifications of equipment and has some storage and handling problems which are not fully known, it would be advisable to use methanol in blends to mitigate those problems. Assuming a 50% volume blend, this market could absorb some 1,500 BPD of methanol (about 190 TPD), 1/ displacing approximately 825 BPD of oil products. 2/

8.54 Thus, the immediate domestic demand for methanol as fuel (250 TPD) represents about 50% of the minimum economic size of a modern methanol plant. The most common size is 1,000 T/SD, export plants being built are in the 2,000-2,500 TPD size range for single train plants. These are the plants that will determine the international trading price for methanol in the future.

8.55 The feasibility of a methanol project will thus depend on additional domestic and export markets. On the domestic side, methanol could provide the first building block for a chemical industry. 3/ For example, half of the world chemical methanol consumption is in formaldehyde production. This product is an input to the manufacture of thermo-setting resins of industrial application, among which the wood industry is very important. Bolivia has a large forestry potential but the size of this potential market has yet to be quantified.

(b) Export Potential:

8.56 Many of the new export methanol plants being built in gas rich countries are high risk ventures, because they gamble on an early development of a large scale fuel market for methanol. It is still uncertain whether this market will develop. It depends on the oil supply balance on the relative economics of adapting the vehicle engines and parts to this new fuel and the feasibility of the methanol to gasoline conversion processes.

1/ Figure includes 100% of kerosene market, and 20% each of diesel and fuel oil demand.

2/ Taking into account the lower calorific content of methanol (8,570 Btu/lb or 3.79 MMBtu/bbl).

3/ To enable the necessary flexibility, the project should be conceived as a chemical-grade methanol plant, which anyway does not appear less cost efficient than a plant producing fuel-grade methanol.

8.57 The mission suggests that Bolivia should study this alternative at the end of the decade. By that time, both the international market balance and the internal supply of liquid hydrocarbons will be better defined.

8.58 At present, 97% of the methanol market is chemical. Most of this market is mature and will increase at a moderate rate in the future. New capacity being built or planned largely exceeds projected chemical methanol demand, and there is a likelihood of significant surplus developing in the 1985-87 period.

8.59 Brazil and Argentina are the only two countries with direct methanol production. Trinidad is the only new country with a firm project. Trinidad has abundant natural gas reserves with a limited domestic market. A methanol plant targeted for exports has been developed as one way to utilize natural gas.

Table 8.8: Central and South American Methanol Capacity - 1979
(Thousand Metric Ton Per Year)

Company	Location	Capacity	Feedstock	Future
Brazil				
Alba	Cubatao, Sao Paulo	20	Fuel Oil	+10 (1980)
Copenor	Camacari, Bahia	60	Nat. Gas	+ 5 (1980)
Prosint	Rio de Janeiro	50	Naphta	+10 (1980
Total		100		
Argentina				
Atanor	Rio Tercero, Cordoba	15	Nat. Gas	+100 (1985)
Casco (Borden)	Pilar, Buenos Aires	20	Nat. Gas	
Total		35		
Trinidad				
National Energy Corporation	Point Lesas	-	Nat. Gas	+440 (1984)
Total		165		

8.60 It is to be noted that the plants in Brazil and Argentina are all below economic size and that those that use as feedstock liquid fuels have a considerably higher production cost. They are justified because their production is captive, used mainly for formaldehyde production. Thus, it can be inferred that the plants in Brazil could have interest in entering into a joint venture with Bolivia not only for methanol but also for formaldehyde production. Brazil needs additional methanol capacity by 1984/85 and already imported 15 thousand tons in 1979 from the USA.

8.61 There are a group of projects to increase the productive capacity of methanol. However, it is estimated that Brazil might become increasingly dependent on methanol imports from lower cost energy centers by the mid to late 1980s. Imports could reach 40-45% of its requirements by the end of the century. A contradictory project is being planned by Copenor. It consists of 1,000 tons per day methanol plant to be on stream by the 1985-87. Originally, the methanol was to be used for the production of chemicals. However, the current plan is for most of the output from the plant to be sold to PETROBRAS for blending with gasoline, which would directly compete with the ethanol program.

8.62 On the Pacific Coast, the market potential for chemical methanol is about 150 T/D in deficit neighbouring countries. But because methanol is a liquid and can be transported by pipeline, Bolivia could enter international trade by using the existing oil pipeline to Arica (Chile).

Table 8.9: Methanol Surplus/(Deficit) Analysis
(Thousand Metric Tons)

	1985	1990	2000
Brazil	(35)	60	(215)
Argentina	(2)	33	(5)
Chile	(30)	(37)	(60)
Peru	(4)	(6)	(14)
Ecuador	(10)	(14)	(30)
Balance	(81)	36	(324)

8.63 International price trends for methanol will depend on the development of a market of some size for methanol as a fuel in developed countries. These prospects depend in turn on the interface between the future prices of methanol and of petroleum products. Given the projected overcapacity, it is likely that there will be a decline of methanol prices in constant terms. The World Bank assumes in its current project evaluations two price scenarios: (a) that methanol will escalate at the same rate as gasoline, and (b) there will be no real term escalation until 1990.

Table 8.10: Methanol Prices Projection
(in 1980 constant US$ per ton of methanol)

	1980	1985	1990
Scenario (a)	220-240	272	307
Scenario (b)	220-240	240	240

Source: World Bank. Methanol: Opportunities for Developing Countries

(c) Production Costs

8.64 The Bank 1/ has estimated the production cost of methanol at US$180/ton, for a 1000 T/D capacity and assuming a 20% rate of return on investments, in constant terms and assuming zero value for gas. Under the constant price scenario, the economic value of gas resulting from such a project would be US$2.0/MCF.

(d) SASOL - Synthol and Arge Liquification Processes:

8.65 Although these technologies are of special interest to Bolivia because they permit production of middle distillates and even heavier products, they cannot be considered at this time. In addition to the high capital cost 2/, and large gas needs, these plants require trained manpower and important volumes of water and waste disposal facilities.

8.68 YPFB's preliminary analysis showed that the Sasol route was much less favorable than the Mobil MTG alternative. It is impossible at this stage of development to judge the relative economics of these routes. It is therefore suggested that Bolivia postpone a decision on this issue. At present there are several new technologies for gas liquification being researched, for example, some development work is being made on ultrasound liquefaction.

1/ World Bank: "Emerging Energy and Chemical Applications for Methanol: Opportunities for Developing Countries". April 1982.
2/ At 14% interest rate, 20 years economic life, the capital cost alone can be estimated at US$38/bbl of refined product.

Gross Domestic Product by Sector of Origin, at Constant Prices
(in million of 1970 US$) 1/

Sector	GDP at Market Prices 1970	1976	1979	1980	1981	Avg. Annual Growth % 1970-76	1976-80	1981
Agriculture	189	251	259	259	261	4.9	0.8	2.1
Trad.	167	212	212					
Nontrad.	22	39	42					
Industry	314	447	470	464	467	6.1	0.6	
Mining	97	113	101	102		2.5	-2.5	0.1
Metallurgy	0	5	7	8		75.8	12.5	n.a.
Manufacturing	150	221	251	247		6.7	2.8	-2.8
Construction	43	61	69	66		6.0	2.0	
Hydrocarbons	10	26	17	16		17.7	-11.4	-7.9
Power	14	21	25	25		7.0	2.9	
Services	537	769	873	887	884	6.2	3.6	n.a.
Transport	78	140	176	179		10.2	6.3	
Other	459	629	697	708		5.4	3.0	
GDP Total	1040	1468	1597	1610	1612	5.9	2.3	-0.6

1/ Exchange rate 1US$ = 11.90 $Bol. 1970

Source: Country Economic Report, September 1982.

Bolivia: Energy Balance - 1981
(original units)

RESOURCES	FUELWOOD MT 1/	BAGASSE MT 2/	HYDRO GWH 3/	OIL CONDENSATE AND N. GASOLINE. Mm^3 4/	NATURAL GAS MMCF 5/	LPG Mm^3 6/	GASOLINES Mm^3 7/	KEROSENE JET FUEL Mm^3	DIESEL OIL Mm^3 8/	FUEL OIL Mm^3	NON-ENERGY PET. PRODUCTS Mm^3 9/	TOTAL PET. PRODUCTS Mm^3	ELECTRICITY GWh 10/	CHARCOAL MT 11/	LOSSES & OWN CONSUMPTION
ACTIVITIES															
PRODUCTION	2,280	850	1,081	1,277	88,430										
Export					(70,689)	(36)	(14)								
Import									44						
Consumption in Export Pipeline					(6,853)										
GROSS DOMESTIC SUPPLY	2,280	850	1,081	1,277	10,888	(36)	(14)	-	44	-	-	(6)	-		
CONVERSION:															
Gas Plants				122	(3,335)	177	-	-	-	-	-	177			
Petroleum Refining				(1410)	(1,058)	88	792	227	280	14	n.s.	1401			50
Lube Plant									(59)		27	(32)			32
YPFB Consumption						n.s.	(5)	(1)	(12)	(1)	n.s.	(19)			
Power Generation			(1081)		(3,858)				(67)			(17)	1719		
Transmission & Dist. Losses					(570)								(275)		
Charcoal Conversion	(140)													21	119
Changes in Stock and Adjustment				11		4	(108)				(1)	(105)			105
SECONDARY DOMESTIC SUPPLY	2140	850	1081	-	2,067	233	665	226	186	13	26	1349			
FUEL BLENDING							(187)	(18)	63	142	-	-			
AVAILABLE FOR DOMESTIC FINAL DEMAND 12/	2140	850	-	-	2,067	233	478	208	249	155	26	1349	1444		
Non-Energy Demand	-	850									26	(26)			
DOMESTIC FINAL ENERGY DEMAND					2,067	233	478	208	249	155	-	1323			
Industry	10				2,062	12		32	39	140	-	223	375	21	
Residential-Comm.	2130				5	215		70				285	636		
Transport															
Road						6	461		172			639			
Air							17	103				120			
Rail and Barge								1	17	4		22			
Mining								2	21	11		34	433		

Source: Mission estimates - see explicative notes for each item.

ENERGY BALANCE
EXPLICATIVE NOTES

1. Fuelwood:

Data includes direct and indirect (charcoal) consumption:

(a) Direct consumption was estimated in 1980 Energy Balance (MEH) at 2,086 Mtons or 730 MTOE, based on partial results of a fuelwood consumption survey. Specific per capita fuelwod consumption by region is estimated at:

Altiplano:	1.88 kg/day/inhabitant
Valleys:	2.51 kg/day/inhabitant
Tropical Lowlands:	3.14 kg/day/inhabitant

Projection to 1981 was made assuming a 2.7% population growth.

(b) Charcoal consumption is based on direct information provided by ENAF. It does not include other industrial charcoal consumption. Wood to charcoal conversion assumes a 35% efficiency.

2. Bagasse:

ENERGY POTENTIAL is calculated using a conservative heating value of 8,800 Btu/kg of bagasse, with 50% moisture content.

ENERGY REQUIREMENTS are calculated in function of volume of sugar cane processed and alcohol produced. The theoretical energy requirements are: (a) 1.38 MMBtu/ton of sugar cane and (b) 0.56 kcal/kcal of ethanol for alcohol production from molasses. Calorific value of ethanol is 5.048 kcal/lts.

Source of information: Tables 1.40 and 1.41.

3. Hydropower:

Volume data:	ENDE's statistics
Conversion factors:	At production level: 2867 kcal/KWh (30% efficiency)
	At consumption level: 860 kcal/KWh (100% efficiency)
Difference:	Allocated to losses 2007 kcal/KWh

4. Crude Oil, Condensates and Natural Gasoline;

Source: Production - YPFB's actual figures. Table 1.12: Input into Refinery Adjusted for Production.

5. Natural Gas:

Net gas production: conversion factor used: 1,114 Btu/CF.
Gas for final demand: conversion factor used: 1,045 Btu/CF
Gas for gas plant: energy content equal to sum of energy content of natural gasoline and LPG
Gas production excludes gas reinjected, gas lift, flared or lost, or used as fuel in field or in gas plants.

Source: Table. 1.22

Petroleum Products:

Source: YPFB computer printouts.

6. LPG:

Includes liquid petroleum gas from refineries and from gas plants.

7. Gasolines:

Includes all automotive and aviation gasolines. A portion of the refinery gasoline stream is also used as refinery fuel; another portion is used as blending stock into the diesel and fuel oil stream. At the refinery level, it also includes the so-called "hydrobon", a light stream that is fed to the platforming unit.

8. Diesel:

Part of the diesel stream is diverted to the lubricant plant. Diesel oil also is the main fuel for power generation in isolated and rural networks. The volume of diesel used by the mining sector is allocated to final consumption although a portion of it is used for power generation.

9. Now energy products are not represented in the balance. These include solvents, ether,asphalt, lube oil, paraffin, etc.

10. Electricity:

Figures represent net generation and were converted at 860 kcal/KWh. Deduction for transmission and distribution losses is equal to 16% of gross generation.

Source: ENDE - 1981.

11. Charcoal:

Represents only the consumption of the ENAF's tin smelter. In 1981 it was 60 tons/day x 365 days/year. Some sources estimate that this company's consumption represents about 85% of total charcoal consumption.

12. Available for final demand:

The allocations to the various consuming sectors were made on the following principles:

Gas:	Actual YPFB's sales distribution reports.
Petroleum Products:	Where not directly available, the distribution used in the 1980 Energy Balance was followed.
Electricity:	ENDE's sales report for 1980.

Bolivia: Energy Balance 1981
(thousands of tons of oil equivalent)

	FUELWOOD	BAGASSE	HYDRO	OIL CONDENSATE AND N.GASOLINE.	NATURAL GAS	LPG	GASOLINES	KEROSENE & JET FUEL	DIESEL OIL	FUEL OIL	ELECTRICITY	CHARCOAL	ENERGY SECT. CONSUMPTION AND LOSSES	STATISCAL ADJUSTMENTS	TOTAL ENERGY
PRODUCTION	798	189	310 b/	1095	2483										4875
Export (Net)					(1862)	(23)	(11)								(1896)
Import									39						39
Consumption in Export Pipeline					(180)										(180)
GROSS DOMESTIC SUPPLY	798	189	310	1095	441	(23)	(11)	-	39	-	-	-	-	-	2838
CONVERSION															
Gas Plants				105	(242)	115							22		-
Petroleum Refineries				(1162)	(28)	57	644	208	197	13			71	24	-
Fower Generation			(310)		(102)				(60)		148		107	217	-
Charcoal Conversion	(49)											16	33		-
Transmission & Distribution Losses					(15)	n.s.	(3)	(1)	(11)	(1)	(24)		55		-
Inefficiency Bagasse Use		(63)											63		-
Statistical Adjustment and Changes in Stock				(14)		3	(90)							101	
TOTAL ENERGY SECTOR CONSUMPTION & ADJUSTMENT													351	342	(693)
SECONDARY DOMESTIC SUPPLY	749	126	-	-	54	152	540	207	165	12	124	16			2145
Fuel Blending							(151)	(16)	51	116					-
AVAILABLE FOR DOMESTIC FINAL DEMAND 12/	749	126	-	-	54	152	389	191	216	128	124	16			2145
Industry	4	126			54	8		28	34	116	32	17			419
Residential-Commercial	745				n.s.	140		62			55				1002
Transport															
Road						4	375		150						529
Air							14	98							112
Rail & Barge								1	15	3					19
Mining								2	17	8	37				64

n.s. = not significant

Source: Mission estimate, based on assumptions explained in notes.

Bolivia: 1981 Final Energy Utilization 1/
(MTOE)

Sectors	Fuelwood	Bagasse	Natural Gas	LPG	Gasolines	Kerosene/ Jet Fuel	Diesel Oil	Fuel Oil	Electricity	Total	Distribution %
Industry	1	42	43	6		4	10	81	32	219	30.0
Residential/Commercial	112			98		19			50	279	38.1
Transport											
Road				1	75		75			151	20.7
Air					3	20				23	3.2
Rail and Barges						–	5	8		10	1.4
Mining						–	5	6	37	48	6.6
Total	113	42	43	105	78	43	98	89	119	730	–
Distribution %	15.5	5.8	5.9	14.4	10.7	5.9	13.3	12.2	16.3	–	100.0

NOTES:
1/ Takes into account approximate efficiencies of energy utilization.
Conversion at following factors:

Commodity	Sector	Efficiency
Fuelwood	Residential/Commercial	15%
	Industry	20%
Bagasse	Industry	33%
Natural Gas	Industry	30%
LPG	Industry	80%
	Residential/Commercial	70%
	Transport-Road	30%
Gasoline	Transport-Road	20%
	Transport-Air	20%
Kerosene	Industry	15%
	Residential/Commercial	30%
	Transport-Rail	15%
	Mining	15%
Jet Fuel	Transport-Air	20%
Diesel Oil	Industry	30%
	Transport-Road	25%
	Transport-Rail-Barges	30%
	Mining	30%
	Others	25%
Fuel Oil	Industry	70%
	Transport-Rail-Barges	50%
	Mining and Others	70%
Electricity	Industry	100%
	Residential/Commercial	90%
	Mining	100%

Bolivia: Energy Balance Projected to 1990 - Base Case
(MTOE)

	Fuelwood	Bagasse	Hydro	Oil, Condensates Natural Gasoline	Natural Gas	LPG	Gasolines	Kerosene Jet Fuel	Diesel Oil	Fuel Oil	Electricity	Charcoal	Energy Sector Cons. & Losses	Total Energy	Total Growth 1990/1981
Production	817	189	310	998	2957									5271	
Export (Net)					(1862)									(1862)	
Import Requirements				610										610	
Consumption in Export Pipeline					(180)									(180)	
Gross Domestic Supply	817	189	310	1608	915									3839	35%
Conversion															
Gas Plants				152	(351)	167							32		
Petroleum Refineries				(1760)	(28)	71	632	291	460	177			157		
Power Generation			(310)		(414)				(98)		231		591		
Charcoal Conversion	(67)											22	45		
Transmission & Distribution Losses					(43)						(30)		73		
Inefficiency in Bagasse Use		(63)											63		
Statistical Adjustment and Changes in Stock															
Total Energy Sector Consumption and Adjustment													961	(961)	
Available for Domestic Final Demand	750	126			79	238	632	291	362	177	201	22		2878	34% 1/
Industry	5	126			79	11		39	47	161	51	22		541	28%
Residential/Commercial	745					220		88			97			1150	13% 2/
Transport															
Road						7	609		244					860	63%
Air							23	159						182	63%
Rail and Barge								2	24	5				31	63%
Mining								3	47	11	53			114	33%

1/ Assumes an average elasticity of 1.2. Elasticity for commercial fuels is 1.7, which appears to be reasonable.
2/ Growth of fuelwood demand assigned to LPG with an efficiency ratio of 1:4.7.

Source: Mission estimate.

Summary of Scenario Specifications

Economic Variables	Baseline Scenario	Accelerated Expansion Scenario
Population Growth	4% urban, 2% rural	same
GDP Growth %	1982 = (5.0%) 1983 = 0.0% 1984 = 1.0% 1985 = 2.0% 1986-90 = 5.0%	same
Industrial Value Added	1982 = -5% 1983 = 0% 1984-85 = 1.5% 1986-90 = 3.5%	same as Baseline plus expansion projects identified by GDC, incl. Ammonia - Urea Plant, Aceile Fino, Molinera Oriente, Hilanderia Santa Cruz, CBN, FNV, SOBOCE
Mining Value Added	Same as industry	Twice the growth of Baseline scenario
Metallurgical Value Added	Vinto & La Palca expansion	Vinto, La Palca and Karachipampa
Agricultural Value Added	1986-90 = 3.5%	1986-90 = 5.0%
<u>Power Growth Rates</u>		
Household/Commercial	Urban Population Growth x 1.20	Urban population growth by 1.4
Manufacturing	Industrial V.A. Growth x 1.30	Industrial VA growth by 1.6
Mining	Mining V.A. Growth x 1.0	Mining VA growth by 1.4
<u>Liquid & Gas Demand Growth</u>		
Household/Commercial	Urban = Urban Pop. Growth x 1.0 Rural = Rural Pop. Growth x 1.0 minus constant fuelwood cons.	same Rural Population Growth x 1.0 minus fuelwood consumption declining at 4%/year
Manufacturing & Metallurgy	Industrial V.A. Growth x 1.0 Vinto and La Palca	As indicated in Table 1. Vinto, La Palca and Karachipampa
Mining	Mining V.A. Growth x 1.0	same
Transportation	GDP Growth x 1.3	GDP Growth x 1.35

Bolivia: Energy Balance Projected to 1990 - Base Case with Substitution
(MTOE)

	Biomass	Hydro	Condensates & Natural Gasoline	Natural Gas	LPG	Gasoline	Kerosene/ Jet Fuel	Diesel	Fuel Oil	Electricity	Charcoal	Energy Sector Consumption and Loss	Total Energy
Production	1006	310	998	3479									5793
Export				(1862)									(1862)
Consumption in Export Pipeline				(180)									(180)
Statistical Adjustment			(18)										(18)
Gross Domestic Supply	1006	310	980	1437									3733
Conversion													
Gas Plants			99	(478)	379 1/								
Refineries			(1079)	(77)	50	585	212	171	12			126	
Power Generation		(310)		(414)				(98)		231		591	
Charcoal Conversion	(67)										22	45	
Losses	(63)									(30)		93	
Adjustment												855	(855)
Available For Final Demand	876	-	-	468	429	585	212	73	12	201	22	-	2878
Industry	131	-	-	337						51	22		541
Residential/Commercial	745	-	-	131	146		31			97			1150
Transport													
Road	-	-			283	562		15					860
Air	-	-				23	159						182
Rail & Barges							19		12				31
Mining							3	58		53			114

1/ Based on 10 MBD LPG production at gas plants.

Bolivia: Energy Balance Projected to 1990 - Base Case with Substitution and Conservation

	Biomass	Hydro	Crude, Condensates & Natural Gasoline	Natural Gas	LPG	Gasolines	Kerosene/ Jet Fuel	Diesel	Fuel Oil	Electricity	Charcoal	Energy Sector Consumption & Losses	Total Energy
Supply													
Production	1006	310	998	3182									5496
Exports				(1862)									(1862)
Consumption in Export Pipeline				(180)									(180)
Statistical Adjustment			(18)										(18)
Gross Domestic Supply	1006	310	980	1140									3436
Conversion													
Gas Plants			99	(478)	379								
Refineries			(1079)	(77)	50	585	212	171	12			126	
Power Generation		(310)		(414)				(98)		231		591	
Charcoal Conversion	(67)										22	45	
Losses	(63)									(30)		93	
Adjustment												855	(855)
Available for Final Supply	876	-	-	171	429	585	212	73	12	201	22	-	2581
Industry	131			171	106				2	51	22		483
Residential/Commercial	745				183		64			97			1089
Transport													
Road					140	562		29					731
Air						23	132						155
Rail and Barges							16		10				26
Mining								44		53			97

Bolivia: Projected Energy Balance to 1990 - Accelerated Growth Case - With Substitution Gas
(MTOE)

	Biomass	Hydro	Oil, Condensates Natural Gasoline	Natural Gas	LPG	Gasolines	Kerosene Jet Fuel	Diesel	Fuel Oil	Electricity	Charcoal	Energy Sector Consumption Non Energy Products	Total Energy	Total Growth 1990/8
Production	777	310	998	4007									6092	
Export (Net)				(1862)									(1862)	
Consumption in Export Pipeline				(180)									(180)	
Statistical Surplus 1/			(18)										(18)	
Gross Domestic Supply	777	310	980	1965									4032	42%
Conversion														
Gas Plants			99	(558)	459 3/							-	-	
Refineries			(1079)	(77)	50	585	212	171	12			126	-	
Power Generation 4/		(310)		(580)				(110)		301		699	-	
Charcoal conversion	(67)										22	45	-	
Losses	(63)									(39)		102		
Adjustments for Energy Sector												972	(972)	
Available for Final Domestic Demand	647	-	-	750	509	585	212	61	12	262	22		3060	43%
Industry	131			573			-			92	22		818	95%
Residential/Commercial	516			177	199	-	20			112			1024	2% 2/
Transport														
Road					310	561	-	11					882	69%
Air						24	165						189	69%
Rail and Barges							20		12				32	69%
Mining							7	50	-	58			115	41%

1/ Crude surplus due to thermal equivalent factor used.
2/ Slow growth is due to reduction in fuelwood and change over to fuels that are used with higher efficiency.
3/ LPG availability calculated on the basis of a 12 MBD prediction from gas plant. Implies full capacity utilization of present Rio Grande Plants.
4/ Power Generation: Gas Based: 58%; Hydro 31%; Diesel 11%.

Bolivia: Changes in the Structure of Supply and Demand to 1990

	1981	Baseline 1990 Without Substitution	Baseline 1990 With Substitution	Baseline 1990 With Substitution & Conservation	Accelerated Growth With Substitution
Primary Fuels for Domestic Market - Total (MTOE)	2838.	3839.	3733.	3436.	4032.
% Share					
Biomass	34.8	26.2	26.9	29.3	19.3
Hydro	10.9	8.1	8.3	9.0	7.7
Oil	38.8	41.9	38.5	28.5	24.3
Gas	15.5	23.8	26.3	33.2	48.7
Losses					
% of Gross Domestic Supply 1/	12.4	25.0	22.9	24.9	24.1
Available for Final Demand (MTOE)	2145.	2878.	2878.	2581.	3060.
% Distribution					
Industry	19.5	18.8	18.8	18.7	26.7
Residential/Commercial	46.7	40.0	40.0	42.2	33.5
Transport	30.8	37.3	37.3	35.3	36.0
Mining	3.0	4.0	4.0	3.8	3.8
Fuels for Domestic Final Supply					
% Share					
Biomass	40.6	31.2	31.1	34.8	21.9
Oil Production	45.7	53.3	32.4	36.1	30.1
LPG from Gas	5.4	5.8	13.2	14.7	15.0
Natural Gas	2.5	2.7	16.3	6.6	24.5
Electricity	5.8	7.0	7.0	7.8	8.5

1/ Losses for 1981 are actual. For 1990, they also include statistical adjustments.

Source: Energy Balances. Annexes 1.3, 1.4, 1.5, 1.6, 1.7.

Bolivia: Long Term Projection of Domestic Gas Requirements
(MTOE)

	1981	1990 (Scenario C)	1995	2000	2005	2010	Accumulated Gas Requirements: MTOE 1981-90	MTOE 1990-2000	MTOE 2000-2010	MTOE 1981-2010	1981-2000 10^9CF	1981-2010 10^9CF
Supply Requirements												
Hydro 1/	310	310	310	310	310	310						
Gas	441	1,140	1,965	3,153	4,408	5,942	7,048	20,558	44,778	72,384	849	2,428
Oil 2/	1,095	980	886	801	724	654						
LPG and Natural Gasoline	57	445	478	478	478	478						
Conversion Processes												
Gas:												
Power Generation 10/	102	414	554	876	1,268	1,788	2,322	5,995	13,000	21,317	315	809
LPG & Nat. Gasoline 3/	242	478	478	478	478	478	3,240	4,780	4,780	12,800 10/	106	169
Refineries 8/	28	77	71	64	58	52	473	708	580	1,761	45	64
Oil:												
Non-Energy Products 4/	16	16	16	16	16	16						
Isolated Power Systems 9/	60	98	119	145	160	177						
Final Demand 5/	2,145	2,581	3,263	4,125	5,019	6,106						
Biomass 1/	891	898	898	898	898	898						
Electricity 6/	124	201	274	374	491	645						
Liquid Hydrocarbons 7/	1,076	1,311	1,229	1,118	1,026	939						
Gas	54	171	862	1,735	2,604	3,624	1,013	9,075	26,418	36,506	383	1,386

1/ Assumed constant over period.
2/ Assumes 2% decline in oil production.
3/ In 1990 includes 10 MBD of LPG and 2.1 MBD of natural gas. Thereafter supply remains constant.
4/ 1.5% of crude production in 1981 - maintained constant over projection period.
5/ Economic growth projected at 4%/year and elasticity of 1.2 to 2000 and 1.0 to 2010.
6/ Economic growth projected at 4%/year and elasticity of 1.6 to 2000 and 1.4 to 2010.
7/ Projection obtained as differential between production less intermediate demand plus LPG and natural gasoline production.
8/ 8% of crude throughput.
9/ Projected at 4% per year to 2000 and 2% thereafter.
10/ Converted at 3.0 MBtu/CF.

ANNEX 1.10

Bolivia: Hydrocarbon Reserves

	Crude Oil MMBLS	Gas in Solution MMMCF	Condensate MBBLS	Free Gas MMMCF
(a) Proven Recoverable Reserves at July 1, 1982 (Class I and II)				
YPFB - Existing Fields	25,518	66	55,907	4,146
Private Companies	-	-	22,455	743
Sub-total	25,518	66	78,362	4,889
(b) Semi-Probable Recoverable Reserves (Class III)				
YPFB	23,403	25	50,365	717
Private Companies	-	-	1,873	226
Sub-total	23,403	25	52,238	943
Total Reserves I, II, III	48,921	91	130,600	5,832
(c) Probable Identified Reserves				
YPFB				
Tacobo	-	-	-	78
Huayco	-	-	-	48
Montecristo	-	-	-	204
Tesoro				
Los Suris	-	-	489	64
Escondido	-	-	6,300	341
Taiguati	-	-	859	38
Sub-total	-	-	7,648	733
PROVEN AND PROBABLE RESERVES TOTAL	48,921	91	138,248	6,605

Class I: Volume recoverable from wells already drilled and in zones that have been perforated.

Class II: Volume recoverable from existing wells in (a) zones not yet perforated; and (b) feasible secondary recovery projects that do not require additional wells.

Class III: Volume to be recovered through (a) drilling of new wells in continuous extensions of fields partially developed and outside of drainage area; (b) feasible secondary recovery projects that require additional wells to be drilled.

Source: Mission estimates based on YPFB data.

Bolivia: Result of Past Exploration - 1960-1980

	RECOVERABLE RESERVES DISCOVERED					PHYSICAL EFFORT			
			Natural Gas (10^9 CF)			Number of			
	Oil (10^6 Bbl)	Condensates (10^6 Bbl)	Oil Fields	Gas Fields	Total 1/ 10^9 CFGE	Exploratory Wells	Successful Wells	Seismic Work (km)	Exploratory Drilling (km)
1960	60.3	0.8	161.3	124.5	597.4	19	3	n.a.	n.a.
1961	9.7	11.6	27.7	574.0	710.3	15	1	n.a.	n.a.
1962	-	70.2	-	1261.0	1619.0	13	1	n.a.	n.a.
1963	-	-	-	-	-	11	2	n.a.	n.a.
1964	8.1	2.6	-8.4	112.9	175.7	10	6	n.a.	n.a.
1965	21	0.7	22.0	-32.6	165.3	9	1	n.a.	n.a.
1966	-	-	-	-	3.1	13	3	n.a.	n.a.
1967	37	-	55.6	39.4	283.7	9		n.a.	n.a.
1968	-	4.4	-	319.6	342.0	10	1	n.a.	n.a.
1969	-	-	-	-	-	5	2	n.a.	n.a.
1970	-	-	-	-	-	4	-	-	-
1971	-	-	-	-	-	6	-	966	52.9
1972	-	0.3	-	17.7	19.2	5	1	2,536	33.8
1973	6.2	0.4	5.2	315.0	353.9	5	3	2,433	33.8
1974	-	-	-	103.0	103.0	5	1	11,012	23.9
1975	-	-	-	0.4	0.4	7	-	16,857	37.0
1976	2	4.1	8.3	94.7	134.3	12	5	11,400	80.6
1977	0.2	3.7	1.1	210.0	231.0	10	4	8,331	78.3
1978	-	36.3	-	949.8	1334.9	13	4	5,269	91.4
1979	-	1.0	-	17.0	22.1	5	1	1,057	64.8
1980	-	9	-	200	245.9	6	0	1,024	74.0
TOTALS	145.1	145.1	289.6	4371.9	6141.2	192	39	60,885	570.5

1/ Cubic feet of gas equivalent. Oil & Condensate converted at 5.1 MCF/bbl.

Source: YPFB information and Mission estimate.

BOLIVIA: LIQUID HYDROCARBONS PRODUCTION MID 1981 FORECAST
(Bbls/Day)

	Fields	Crude and Condensate Reserves July 1, 1981 (MBbls) Proven I & II	Proven III	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	Accumulated Production 1982-90 (MBbl)	Remaining Reserves I, II & III (MBbl)
CRUDE AND CONDENSATE															
YPFB	Caranda	8875	6925	1150	1150	950	750	600	450	350	300	250	200	1825	13,975
	Colpa	4227	714	1000	762	1000	1100	900	800	700	600	500	500	2505	2,436
	Rio Grande	20554	2823	8926	7640	6900	6500	6000	5400	4800	4300	3800	3400	17790	5,587
	La Pena	3077	394	1308	1250	1000	750	550	400	300	250	150	100	1734	1,737
	Palmar	1781	-	804	960	950	800	500	400	250	150	150	100	1555	226
	Naranjillos	816	-	-	-	-	-	-	-	300	200	200	200	329	487
	Enconada	289	1215	-	-	-	-	-	400	400	400	400	400	730	774
	Yapacani	4400	NA	-	-	-	-	-	1300	1300	1300	1300	1200	2336	2,064
	Palometas	395	NA	-	-	-	-	-	-	-	-	-	-	-	395
	Santa Rosa	1536	226	-	-	-	-	-	400	400	400	400	400	730	1,032
	Palacios	957	NA	-	-	-	-	-	-	-	-	-	-	-	957
	Santa Cruz	100			50	50	50	50	-	-	-	-	-	73	27
	Camiri	2752	7548	886*	875	800	700	1100	2350	3000	2650	2350	2050	5794	4,506
	Monteagudo	10112	8907	2446	2090	1700	1900	2050	2750	4300	5200	4000	3150	9906	9,113
	Tatarenda	200	-	233	325	250	200	150	150	100	100	-	-	465	(265)
	Caigua	48	524	94	50	-	-	-	-	-	-	-	-	18	554
	Bermejo	292	-	100	200	150	150	100	100	100	50	50	-	329	(37)
	Sanandita	0			125	100	100	50	50	50	50	50	-	210	(210)
	Cambeiti	1284	-	214*	150	100	50	50	-	-	-	-	-	128	1,150
	Vuelta Grande	23500	28150	6	3000	7500	7000	6000	5600	5150	4700	4400	4400	35,827	
	Espino	747	679	662	690	1150	650	300	200	150	100	50	-	1201	225
Occid.	Tita	1318	-	1373	725	400	250	150	100	-	-	-	-	593	725
Tesoro.	La Vertiente	3174		1409	1760	1500	1500	1500	1500	1500	1500	1500	1500	5022	(1848)
Occid.	Porvenir	22009	2715	988	6550	7700	5850	4050	2400	1500	1200	1000	800	10968	13756
	Other Fields	427	14931	405*	-	-	-	-	-	-	-	-	-	-	15358
TOTAL CRUDE CONDENSATE		112,870	75,751	22,004	25,352	27,700	28,800	25,100	25,150	25,100	23,900	20,850	18,400	80,064	108,557
OF WHICH NEW PRODUCTION					1,725	7,200	10,400	10,220	13,300	15,350	15,700	14,050	12,900	36,808	
NATURAL GASOLINE															
YPFB	Rio Grande			2003	1900	2400	2400	2400	2400	2400	2400	2400	2400		
	Camiri			101											
TOTAL NATURAL GASOLINE				2104	1,900	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400		
OF WHICH NEW PRODUCTION					450	450	450	450	450	450	450	450	1,314		
LPG															
YPFB	Rio Grande			2940	4485	4660	4660	4660	4660	4660	4660	4660	4660	15244	
	Colpa				349	1048	990	932	815	640	524	466	350	2232	
	Camiri			104	175	186	175	163	151	151	140	140	140	519	
	Vuelta Grande			-	-	-	-	-	4077	4077	4077	4077	4077	7441	
Occid.	Porvenir			-	-	-	2912	2912	2912	2912	2912	2912	2912	7440	
TOTAL LPG				3044	5,009	5,894	8,737	8,667	12,615	12,440	12,313	12,255	12,139	32,876	
OF WHICH NEW PRODUCTION					110	1,002	3,845	3,775	7,724	7,607	7,479	7,421	7,363	16,909	
GRAND TOTAL															
TOTAL LIQUID PRODUCTION				27,152	32,261	35,994	39,937	36,167	40,165	39,940	38,613	35,505	32,939	120,642	
TOTAL NEW PRODUCTION					1,835	8,652	14,695	14,445	21,474	23,407	23,629	21,921	20,713	55,031	

* Production Included in "Other Fields"

Source: YPFB Internal Projections

ANNEX 1.13

REVISED FORECAST

BOLIVIA: LIQUID HYDROCARBONS PRODUCTION FORECAST
(Bbls/Day)

	Fields	Crude and Condensate Reserves July 1, 1981 (MBbls) Proven I & II	Proven III	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
CRUDE AND CONDENSATE													
YPFB	Caranda	8875	6925	1150	1150	950	750	600	450	350	300	250	200
	Colpa	4227	714	1000	762	1000	1100	900	800	700	600	500	500
	Rio Grande	20554	2823	8926	7640	6900	6500	6000	5400	4800	4300	3800	3400
	La Pena	3077	394	1308	1250	1000	750	550	400	300	250	150	100
	Palmar	1781	-	804	960	950	800	500	400	250	150	150	100
	Naranjillos	816	-	-	-	-	-	-	-	300	200	200	200
	Enconada	289	1215	-	-	-	-	-	400	400	400	400	400
	Yapacani	4400	N.A.	-	-	-	-	-	1300	1300	1300	1300	1200
	Palometas	395	N.A.	-	-	-	-	-	-	-	-	-	-
	Santa Rosa	1536	226	-	-	-	-	-	400	400	400	400	400
	Palacios	957	N.A.	-	-	-	-	-	-	-	-	-	-
	Santa Cruz	100	-	-	50	50	50	50	-	-	-	-	-
	Camiri	2752	7548	886 1/	875	800	700	1100	2350	3000	2650	2350	2050
	Monteagudo	10112	8907	2446	2090	1700	1450	1240	1650	1800	2400	3800	5200
	Tatarenda	200	-	233	325	250	200	150	150	100	100	-	-
	Caigua	48	524	94	50	-	-	-	-	-	-	-	-
	Bermejo	292	-	100	200	150	150	100	100	100	50	50	-
	Sanandita	0	-	-	125	100	100	50	50	50	50	50	-
	Cambeiti	1284	-	214 1/	150	100	50	50	-	-	-	-	-
	Vuelta Grande	23500	28150	6	-	-	-	-	7400	7400	7100	6600	6000
	Espino	747	679	662	690	1150	650	300	200	150	100	50	-
Occid.	Tita	1318	-	1373	725	400	250	150	100	-	-	-	-
Tesoro.	La Vertiente	3174		1409	1760	1500	1500	1500	1500	1500	1500	1500	1500
Occid.	Porvenir	22009	2715	988	6550	7700	5850	4050	2400	1500	1200	1000	800
	Other Fields	427	14931	405 1/	-	-	-	-	-	-	-	-	-
TOTAL CRUDE CONDENSATE		112,870	75,751	22,004	25,352	24,700	20,850	17,290	25,450	24,400	23,050	22,550	20,050
NATURAL GASOLINE													
YPFB	Rio Grande			2003	2000	2000	2000	2000	2000	2000	2000	2000	2000
	Camiri			101	100	100	100	100	100	100	100	100	100
TOTAL NATURAL GASOLINE				2104	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100	2,100
LPG													
YPFB	Rio Grande			2940	2900	2900	2900	2900	2900	2900	2900	2900	2900
	Colpa 2/												
	Camiri			104	175	186	175	163	151	151	140	140	140
	Vuelta Grande			-	-	-	-	-	-	4077	4077	4077	4077
Occid.	Porvenir			-	-	-	2912	2912	2912	2912	2912	2912	2912
TOTAL LPG				3044	3,075	3,086	5,987	5,975	5,963	10,040	10,040	10,040	10,040
GRAND TOTAL TOTAL LIQUID PRODUCTION				27,152	30,527	29,886	28,937	25,365	33,513	36,540	35,190	34,690	34,190

1/ Production included in "Other Fields"

2/ Used for injection at La Pena.

Source: Energy Assessment Division Estimates

ANNEX 1.14

Bolivia: 1981 Refining Capacity

	Capacity MBD	Throughput MBD
Cochabamba:		
Primary Distillation:		
New Unit 1/	27,500	15,215
Old Unit	19,000	-
Hydrobon - Platforming	7,000	2,607
Gas Plant (LPG ton/day)	230	90
Lube Oils	444	
Energy Consumption (gasoline)		860
As % of throughput		5.7%
Santa Cruz:		
Primary Distillation:		
New Unit 1/	15,000	7,249.7
Old Unit	5,000	-
Hydrobon - Platforming	6,400	1,910
Gas Plant (LPG tons/day)	na	38
Energy Consumption (natural gas)		864.9×10^6 CF
as % of throughput		6.2%
Sucre:		
Primary Distillation	3,000	1,803.8
Energy Consumption (natural gas)		193.8×10^6 CF
as % of throughput		5.6%

1/ These units were built at a cost of US$ 190 million and commissioned in 1978.

na: Information not available

Source: YPFB and mission estimates.

BOLIVIA: GASOLINE BALANCE 1981
(m^3)

REFINERIES	COCHABAMBA	%	PALMASOLA	%	SUCRE	%	FIELD REF. (BOLSILLE)	%	TOTAL PRODUCTION	TOTAL SALES	DIFFERENCE PROD. - SALES
First Stage Processing											
White Gasoline	-				41,184		673		41,857		
Light Gasoline	167,828		73,540		-				241,369		
Medium Gasoline	196,018		50,194		-				246,212		
Hydrobon	151,280		110,859						262,139		
Total Gas Stream	515,127	58	234,593	56	41,184	39	673	53	791,577 (56)		
Total Processed	883,040		420,758		104,687		1,269		1,409,754		
Reprocessed Gasolines											
Motor Extra (75 octanes)	13,575				927				14,502	6,548	7,954
Motor Superior (82 oct.)	287,605		107,834		36,695				432,134	435,196	(3,062)
Motor Premium (92 oct.)	9,868		9,952		2,938		-		22,758	18,482	4,276
Aviation (100/130)	18,694				-		-		18,694	17,324	1,370
White Gasoline					466				466	789	(323)
Aviation Gas (80/87)	8								8	8	-
Total Finished Gasoline	329,750	—	117,786	—	41,026	—	-	—	488,562	478,347	10,215
Production Difference — Gasoline Streams Finished Gasoline	185,377		116,807		158		673		303,015		

ANNEX 1.16

BOLIVIA: Petroleum Product Sales on Domestic Market
(M^3)

	Gasolines	Kerosene	Diesel	F.O.	L.P.G.	Aviation Fuels	Other Fuels	Total	GDP
1971	278.929	129.312	91.789	110.606	11.723	34.222	562	657.143	12.985
1972	292.315	138.760	100.988	117.239	16.086	36.633	716	702.737	13.732
1973	307.357	150.743	114.368	116.889	23.275	40.744	753	754.129	14.668
1974	326.547	160.631	135.454	136.953	35.484	52.499	734	848.302	15.563
1975	364.579	167.224	173.404	144.712	51.352	68.532	750	970.553	16.353
1976	385.599	171.761	207.711	149.689	64.909	77.584	797	1058.050	17.469
1977	415.265	172.814	257.719	164.299	84.824	91.453	991	1187.365	18.064
1978	438.238	173.817	292.540	161.493	104.378	106.888	1146	1278.500	18.628
1979	452.438	165.214	292.632	148.672	126.736	119.701	1292	1306.685	19.007
1980	461.528	150.485	299.080	152.334	175.931	124.825	1466	1365.649	19.161
1981	460.249	105.306	299.846	155.054	233.182	104.282	2167	1360.086	19.353
GROWTH RATE (%/year)	5.807	-0.215	14.63	3.623	34.19	15.05		8.507	4.237
Elasticity Oil Consumption/GDP	1.37	(0.051)	3.45	0.86	8.07	3.552		2.008	

Bolivia: 1981 Sales of Petroleum Products on the Internal Market

	B/D	%
Gasoline - Extra	112.82	0.5
Superior	7498.48	31.3
Premium	318.46	1.3
Gasoline White	13.60	-
Ether	1.46	-
Solvent	22.28	0.1
Kerosene	1814.34	7.6
Diesel	5166.13	21.6
Fuel oil	2671.47	11.2
LPG - Domestic	3707.39	15.5
Industrial 1/	202.04	0.8
Automobile	108.38	0.5
Aviation gasoline 80/87 oct.	0.13	-
" " 100/130 oct.	84.42	0.4
" " 100 car	214.07	0.9
Jet Fuel Lab	1284.10	5.4
Jet Fuel A-1	480.25	2.0
Aviation Oils	7.39	-
Automobile Oil	209.34	0.9
Asphalt - Cement	12.05	-
	23,928.6	100.0

1/ Propane and butane added to this category source. Mission estimate from YPFB sales data.

ANNEX 1-18

Foreign Trade Alternatives for Petroleum Products
(in US$/bbl) 1/

Import	Price fob	Transport Cost Maritime	Transport Cost Overland	Price cif
From Caribbean				
Gasoil-Diesel (45 cetane)	32.76	2.31	6.88	41.95
Fuel Oil (0.3% S)	33.70	2.50	6.88	43.08
From Ecuador				
Fuel Oil	32.3	1.12	6.88	40.30

Export	Price	Transport Cost Maritime	Transport Cost Overland	fob Bolivia
To Caribbean				
LPG (ton)	250.0	33.77	62.65	153.58
Gasoline	37.8	2.19	1.45	34.16
To Ecuador				
Gasoline	35.9	0.98	1.45	33.47

1/ Calculated on the basis of posted prices - Caribbean - March 1982.

Source: Mission estimates.

Bolivia: Gas Supply - Oil Fields

Fields	RESERVES (10^9CF)					PRODUCTION (10^6CFD)			
	Year Discovered	Originally Discovered	Proven Class I & II	Class III	Original Gas/Oil Ratio	1981 Actual	Production (10^6 CFD) 1985	1990	2000
Subandean									
Bermejo	Pre-1960	0.1	0.5						
Toro	" "	-	0.5	-	-	-	-	-	-
Sanandita	" "								
Camiri	" "	137.2	3.6	1.7	2,419	2	2	1	-
Camatindi	" "	-	-	-	-	-	-	-	-
Los Monos	" "	9.8	8.9	0.3	6,666	-	-	-	-
Guayruy	" "	-	-	-	-	-	-	-	-
Buena Vista	" "	-	-	-	-	-	-	-	-
Tatarenda	1962	2.2	2.2	-	554	-	-	-	-
San Alberto		-	-	-	-	-	-	-	-
Monteagudo	1967	95.0	57.4	-	2,564	7	6	6	6
Caigua	1973	5.2	1.1	-	851	-	-	-	-
Cambeiti	1976	8.3	5.6	-	4,213	-	-	-	-
Espejos	1979	-	-	-	-	-	-	-	-
Lowland									
Caranda	1960	285.8	173.6	24.2	4,256	20	19	16	12
La Pena	1965	54.5	25.7	3.4	2,682	2	1	1	-
TOTAL		598.1	279.1	29.6		31	28	24	18

Source: YPFB internal data, updated to July 1982.

Bolivia: Gas Supply - Condensate Fields

Fields	RESERVES (10^9CF)					PRODUCTION (10^6CFD)			
	Year Discovered	Originally Discovered I & II	Estimated Proven 7/1/81 Cat. I-II	Estimated Proven 7/1/81 III	Original Gas/Oil Ratio CF/B	1981 Actual	Projected 1985	Projected 1990	Projected 2000
Lowlands									
Madrejones	1959	16.7	16.7	0	13,916	-	-	-	-
Colpa	1961	601.4	235.8	59.6	30,192	45	40	28	20
Rio Grande	1961	1,261.3	1,028.0	92.4	17,249	57	113	167	236
Palmar	1964	41.1	18.1	2.1	39,324	20	16	5	-
Santa Cruz	-	3.9	3.5	-	35,000	4	2	-	-
Montecristo	1976	0.4	0.4	288.6	29,518	-	-	-	-
Tita-Techi	1976	94.3	20.3	-	8,507	30	7	-	-
Nupuco	1979	0.2	0.2	-	21,000	-	-	-	-
La Vertiente	1978	210.8	174.5	-	43,604	50	50	50	50
Vuelta Grande	1978	838.5	838.5	-	9,430	-	-	-	-
Porvenir	1978	107.0	106.3	-	29,847	-	50	44	-
Espino	1979	16.4	6.7	23.0	22,222	12	7	-	-
TOTAL			2,449.0	465.7		218	285	294	306

Source: YPFB - internal information. Updated to July 1982.

Note: The Mission obtained several reserve estimates, two of which are dated July 1981 and the others relate to earlier assessments. There are discrepancies between the two recent ones and there is no way to relate changes from one year to another. This indicates that reserves estimates are being manipulated incorrectly and do not merit confidence.

Bolivia: Gas Supply - "Mainly Gas Fields"

Field	Year Discovered	RESERVES (10^9CF) Originally Discovered	Estimated July 1981 Prov. I & II	Estimated July 1981 III	Original Gas/Oil Ratio MCF/B	PRODUCTION (10^6CFD) 1981 Actual	Projection 1985	Projection 1990	Projection 2000
Subandean									
Bulo Bulo						-	-	-	-
Lowlands									
Naranjillos	1964	876.4	75.8	-	90	-	-	20	-
Yapacani	1968	319.6	319.6	134.6	103	-	100	100	-
Enconada	1972	17.7	17.7	74.6	61	-	30	30	-
Palometas	1973	315.0	315.0	-	807	-	-	-	70
Santa Rosa	1973	947.0	947.0	144.0	620.0	-	180	180	130
Palacios	1974	103.6	103.6	-	108	-	-	-	30
Rio Seco (GE)		4.8	4.8	4.6	157	-	-	-	-
TOTAL			1,783.5	357.8	—	-	310	330	230

Source: YPDB - internal information

ANNEX 1.22

Bolivia: 1981 Gas Utilization
(10^6 CF)

	Economic Use in Field, Market or Processing	Reinjection and Gas Lift	Lost or Burned	Total
Oil Fields				
Bermejo			157	
Caigua			32	
Camiri	660	2,616	256	
Cambeiti			423	
Monteagudo	1,368		578	
San Alberto			11	
La Pena	642		618	
Caranda	435	3,658	711	
Sub-Total	3,105	6,274	2,786	12,165
Share (%)	25	52	23	
Condensate Fields				
Espino	4,593		402	
Palmar	7,377		169	
Colpa	16,300		1,451	
Rio Grande	24,709	68,172	1,379	
Tita	16,593			
Porvenir	513			
La Vertiente	16,597		4,998	
Sub-Total	86,682	68,172	8,399	163,253
Share (%)	53	42	5	
TOTAL	89,787	74,446	11,185	175,418
Share (%)	51	42	6	

Source: YPFB - Computer Printouts

1981 YPFB Oil and Gas Sales to Industry
(MTOE)

Departments	Diesel Oil 1/	Fuel Oil	LPG	Gas	Total
La Paz	20.64	47.00	2.61	-	70.24
Oruro	15.04	55.17	1.85	-	72.06
Cochabamba	14.71	30.32	2.86	-	47.89
Potosi	5.67	5.35	0.07	-	11.09
Sucre	3.17	0.92	0.08	30.08	34.25
Camiri	1.09	.	.	2.60	3.69
Sub-total	60.32	138.76	7.47	32.68	239.23
Santa Cruz	32.74	2.57	0.08	108.38	143.77
Tarija	0.95	2.56	-	3.41	6.92
Bermejo	0.95	2.56	-	3.41	6.92
Rest of Country	8.60	0.25	0.09	0.35	9.29
TOTAL	106.62	146.47	7.56	144.82	405.47

1/ Assumes that 40% of diesel sales are industrial. A portion of this volume should be allocated to intermediate demand, because it is used to generate electricity.

Source: YPFB - sales statistics; does not include consumption in refineries.

Bolivia: Potential Market for Natural Gas
(MMCFD/Day)

	Actual	Base Case				Optimistic Case		Pessimistic Case	
	1981	1986	1991	1996	2001	1991	2001	1991	2001
La Paz	-	7.4	9.5	12.9	18.7	10.3	21.6	7.8	12.7
Oruro	-	4.8	5.9	7.5	10.1	10.3	16.7	5.4	8.1
Cochabamba	-	10.6	13.8	15.9	19.4	14.9	22.2	13.1	16.5
Potosi	-	5.5	6.4	6.5	6.6	6.4	6.6	5.5	6.5
Chuquisaca	3.6	4.7	5.2	6.1	7.5	5.6	8.0	4.9	6.3
Sub-Total	3.6	33.0	40.8	48.9	62.3	47.5	75.1	36.7	50.1
Santa Cruz	15.5	25.9	26.9	28.5	31.0	48.4	79.0	26.5	50.1
Tarija	0.4	1.5	2.1	2.5	2.8	2.2	2.9	2.1	2.6
TOTAL	19.5	60.4	69.8	79.9	96.1	98.1	157.0	65.3	81.7

Source: GDC. The Internal Demand for Natural Gas and LPG in Bolivia.

ANNEX 1.25

Potential Market for Natural Gas

	Main Fuel	1981 MTOE	1990 Baseline MTOE	1990 Accelerated MTOE	1981 MMCFD	1990 Baseline MMCFD	1990 Accelerated MMCFD
La Paz							
Cerveceria Bol. N.	F.O.	3.5	6.0	6.0	0.4	0.6	0.6
Fca. Nacional Vidrio	F.O.	8.6	11.2	23.0	0.9	1.2	2.4
Fanviplan (Glass)	F.O.	6.8	6.8	8.0	0.7	0.7	0.8
Soboce (Cement)	F.O.	17.5	23.0	27.0	1.8	2.4	2.8
Subtotal		36.4	47.0	64.0	3.8	4.9	6.6
Other Industries	F.O.	10.6	12.0	18.0	1.1	1.2	1.9
Other Industries	LPG	2.6	3.0	4.0	0.3	0.3	0.4
Other Industries	Diesel	20.6	22.0	26.0	2.1	2.3	2.7
Total Industrial Fuels		70.2	84.0	112.0	7.3	8.7	11.6
Oruro							
ENAF (Smelter)	F.O.	51.7	71.0	71.0	5.3	7.4	7.4
Other Industries	F.O.	3.5	4.0	5.0	0.4	0.4	0.5
Other Industries	LPG	1.9	2.0	2.5	0.2	0.2	0.3
Other Industries	Diesel	15.0	18.0	20.0	1.6	1.9	2.0
Machacamarca (Smelter) 1/		-	-	-	-	-	(2.7)
Cement Plant 1/		-	-	-	-		(2.6)
Total Industrial Fuels		72.1	95.0	98.5	7.5	9.9	10.2
Cochabamba							
Coboce (Cement)	F.O.	13.8	28.0	28.0	1.4	2.9	2.9
Vidriolux	F.O.	6.1	10.0	11.0	0.6	1.1	1.2
Industrias de Aceite	F.O.	2.8	4.0	4.0	0.3	0.4	0.4
Subtotal		22.7	42.0	43.0	4.7	4.7	4.7
Refinery	Gasoline	45.0	45.0	45.0	4.7	4.7	4.7
Other Industries	F.O.	7.6	10.0	13.0	0.8	1.0	1.4
Other Industries	LPG	2.8	3.6	3.6	0.3	0.4	0.4
Other Industries	Diesel	14.7	19.0	20.0	1.5	1.9	2.0
Total Industrial Fuels		92.8	119.6	124.6	9.6	12.4	13.0
Potosi							
La Palca	F.O.	4.0	26.0	26.0	0.4	2.7	2.7
ENDE	Diesel	1.0	17.0	17.0	0.1	1.8	1.8
Subtotal		5.0	43.0	43.0	0.5	4.5	4.5
Other Industries	F.O.	1.3	1.7	1.7	0.1	0.2	0.2
Other Industries	LPG	0.1	0.2	0.2	-	-	-
Other Industries	Diesel	4.7	6.0	6.0	0.5	0.6	0.6
Karachipampa				16.0			1.8
Total Industrial Fuels		11.1	50.9	66.9	1.1	5.3	7.1
Sucre							
Fancesa	NG	13.0	28.0	28.0	1.3	2.9	2.9
YPFB-Refinery	NG	5.0	5.0	5.0	0.5	0.5	0.5
ENDE-Power	NG	17.0	17.0	17.0	1.8	1.8	1.8
Subtotal		35.0	50.0	50.0	3.6	5.2	5.2
Other Industrial	F.O.	0.9	1.2	2.0	0.1	0.1	0.2
Other Industrial	Diesel	3.2	4.0	4.0	0.3	0.4	0.4
Total Industrial Fuels		39.1	55.2	56.0	4.0	5.7	5.8
Santa Cruz							
Aceitera Oriente	NG	3.5	4.0	4.0	0.4	0.4	0.4
Other Industry	NG	19.5	28.0	30.0	2.0	2.9	3.1
YPFB-Refinery	NG	23.0	23.0	23.0	2.4	2.4	2.4
ENDE-Power	NG	85.0	238.0	626.3	8.8	24.8	65.3
Subtotal		131.0	293.0	683.3	13.6	30.5	71.2
Other Industry	F.O.	2.6	3.8	3.8	0.3	0.4	0.4
Other Industry	Diesel	32.7	48.0	48.0	3.4	5.0	5.0
Ammonia-Urea Project		-	-	77.0	-	-	8.0
Sponge Iron-Plant 1/							(17.9)
Mutun Ore Processing 1/							(5.8)
Total		166.0	344.8	812.1	17.3	35.9	84.6
Tarija							
Criosal	F.O.	2.0	4.0	4.0	0.2	0.4	0.4
Bermejo Sugar Mills	F.O. Bagasse	3.0	5.0	5.0	0.3	0.5	0.5
with Paper Mill) 1/					-	-	(4.1)
Paper Plant		-	5.0	5.0	-	0.5	0.5
Cement Plant 1/		-	-	-	-	-	(1.2)
Other Industries	Diesel	7.0	10.0	10.0	0.7	1.0	1.0
Total		12.0	24.0	24.0	1.2	2.5	2.5
TOTAL COUNTRY							
Manufacturing		245.0	344.0	460.0	25.0	36.0	47.0
Metallurgy		52.0	97.0	113.0	5.0	10.0	12.0
Power Plants		103.0	272.0	660.0	11.0	28.0	69.0
Refineries		73.0	73.0	73.0	8.0	8.0	8.0
Total		473.0	786.0	1306.0	490.0	82.0	136.0

1/ It is assumed that the marked projects will not be implemented during the present decade. Their joint additional demand would sum 34 MMCFD of which 26 in metallurgy (Machacamarca) and 9 MMCFD in manufacturing substitution of bagasse in sugar mills (3.5 MMCFD), cement plants in Tarija, and Oruro, etc.

Source: Mission estimates.

ANNEX 1.26

BOLIVIA: List of Identified Hydroelectric Projects

Name of Project	River	Type 1/	Capacity (MW)	Energy (GWh)	Present Status 2/	Unit Investment Cost 3/ US$/kW	Year of Estimation
1. San Jacinto	Tolomosa	E/I	7	21	FD	5,000	80
2. Sakhahuaya	Unduavi/Taquesi	E	72	362	FD	1,760	81
3. Icla	Pilcomayo	E/I	90	365	FD	1,860	79
4. Misicuni	Misicune	E/I	104	460	FD	2,040	78
5. Rositas	Rio Grande	E/I	400	2,060	F	1,500	76
6. Aguas Calientes I	Pilaya	E	90	579	F	1,290	81
7. San Jose	Paracti	E	150	840	PF	1,250	76
8. Palillada	Miguillas	E	110	632	PF	1,040	76
9. Tirata	La Paz	E	94	409	P	2,800	76
10. Lloja	La Paz	E	130	583	P	2,000	76
11. Huara	La Paz	E	100	380	P	2,000	76
12. Santa Rosa	Tamampaya	E	23	105	P	1,800	76
13. Umabama	Tamampaya	E	37.5	160	P	1,000	76
14. Ilumaya	Tamampaya	E	54	235	P	900	76
15. Imamblaya	Tamampaya	E	80.8	455	P	1,600	76
16. Siete Lomas	Tamampaya	E	242	1,039	P	900	76
17. Condor Cala	Miguillas	E	75	350	P	1,900	76
18. Tangara	Miguillas	E	108	715	P	1,200	76
19. Tiquimami	Coroico	E	50	340	P	1,000	76
20. Pabellonani	Coroico	E	50	337	P	800	76
21. Huancane	Coroico	E	110	760	P	1,000	76
22. Challa	Coroico	E	35	235	P	900	76
23. Choro	Coroico	E	100	740	P	900	76
24. Bala	Beni	E	1,608	10,600	P	--	--
25. Cachuela Esperanza	Beni	E	10	40	P	--	--
26. Huaji	Zongo	E	26	125	P	1,800	81
27. Pachalaca	Zongo	E	14	67	P	2,200	81
28. Banda Azul	Paracti	E	114	635	P	800	76
29. La Vina	Rio Grande	E	70	247	P	--	--
30. Molineros	Rio Grande	E	130	569	P	--	--
31. Pucara	Rio Grande	E	182	797	P	--	--
32. Caine	Rio Grande	E	162	1,254	P	--	--
33. Puente Arce	Rio Grande	E	130	550	P	800	72
34. Charobamba	Rio Grande	E	214	550	P	--	--
35. Seripona	Rio Grande	E	420	1,700	P	600	72
36. Canahuecal	Rio Grande	E	500	2,000	P	600	72
37. Las Juntas	Rio Grande	E	172	1,350	P	800	72
38. La Higuera	Rio Grande	E	320	1,340	P	700	72
39. Pena Blanca	Rio Grande	E	520	2,490	P	600	72
40. La Pesca	Rio Grande	E	740	3,030	P	600	72
41. Turuchipa	Pilcomayo	E	66	286	P	--	--
42. San Jose	Pilcomayo	E	280	1,226	P	--	--
43. Esperanza	Pilcomayo	E	123	539	P	--	--
44. Sta. Elena	Pilcomayo	E	341	1,494	P	--	--
45. Machigua	Pilcomayo-Pilaya	E	202	885	P	--	--
46. Yuquirenda	Pilcomayo	E	255	1,116	P	--	--
47. Chorro	Pilcomayo	E	244	1,070	P	--	--
48. Paichu	Pilaya	E	204	1,019	P	1,300	81
49. Aguas Calientes II	Pilaya	E	181	764	P	800	81
50. Arenales	Pilaya	E	94	412	P	--	--
51. El Pescado	Pilaya	E	202	885	P	--	--
52. Incahuasi	Pilaya	E	24		P	--	--
53. Las Pavas	Bermejo	E, BN	147/2	400/2	PF	2,000	79
54. Arrazayal	Bermejo	E, BN	166/2	521/2	P	2,000	79
55. Desecho Chico	Bermejo	E, BN	36/2	78/2	P	600	79
56. Cambari	Tarija	E	136	613	P	700	79
57. Astilleros	Tarija	E, BN	106/2	504/2	P	6,200	79
58. San Telmo	Tarija	E, BN	68.5/2	275/2	P	--	--
59. Polvarada	Tarija	E, BN	27/2	60/2	P	--	79
60. Juntas San Antonio	Bermejo-Tarija	E, BN	48/2	165/2	P	--	--
TOTAL			10,295.55	50,816.5			

1/ Type of Project: E = energy; E/I - energy and irrigation, BN = binational.

2/ Present Status of the Project: FD = final designs ready or being prepared; F = feasibility study ready; PF = pre-feasibility studies; P = preliminary studies only.

3/ Unit cost referred to January 1981 price levels using inflation indices. Costs for projects with only preliminary studies are rough estimates.

Bolivia: 1981 Power Generation Capacity
(MW)

	Nameplate			Effective			
	Hydro	Thermal	Total	Hydro	Thermal	Total	% of Total
ENDE	108	113	221	105	101	206	50.7
BPC	142	-	142	128	-	128	31.6
CESSA	2	-	2	-	-	-	-
ELFEC	6	-	6	2	-	2	0.5
OTHER PUBLIC SERV. 1/	1	26	27	-	20	20	4.9
COMIBOL	22	20	42	13	4	17	4.2
OTHER SELF PRODUCERS	6	54	60	3	30	33	8.1
TOTAL	287	213	500	251	155	406	100.0
PERCENTAGE OF TOTAL				62	38	100	

1/ Trinidad, Tarija, Pueblos, etc.

Bolivia: Statistical Data and Forecast for the Power Sector
Peak Demand (MW)

Year	Northern System	Central System	Southern System	Oriental System	Other Areas	Total Country	NIS Demand	Diversity Factor
Actual								
1975	71.6	64.0	23.6	18.2	41.7	219.1		
1976	73.6	67.6	25.5	21.5	42.2	230.4		
1977	77.6	77.0	27.2	26.7	45.0	253.5		
1978	82.4	85.2	27.0	31.9	49.3	275.8		
1979	91.3	88.5	28.8	37.3	50.9	296.8		
1980	98.7*	95.2	29.7	46.7	51.2	321.5*		
1975-80 Growth %	6.6*	8.3	4.7	20.7	4.2	8.0		
1981	103.5* 1/	101.5*	31.7*	51.2	53.3	341.2*	236.7* 2/	
Forecast								
1982	116.6	114.6	35.6	60.2	56.9	376.6	259.0	0.97
1983	119.4	124.3	40.1	70.1	59.4	409.3	275.4	0.97
1984	123.4	134.9	44.6	81.6	62.7	445.1	293.9	0.97
1985	128.3	146.3	48.6	95.0	67.6	485.8	401.5 3/	0.96
1980-85 Growth %	5.3	9.0	10.4	15.3	5.7	8.6	8.2	
1986	137.5	157.8	52.8	105.8	83.8	537.7	435.7	0.96
1987	145.5	170.3	57.5	117.4	87.5	578.2	471.1	0.96
1988	153.8	183.7	62.5	130.3	91.4	621.6	509.1	0.96
1989	162.7	198.3	67.9	144.7	95.4	669.0	550.7	0.96
1990	171.9	213.9	73.9	160.5	99.5	719.2	595.4	0.96
1985-90 Growth %	6.0	7.9	8.7	11.1	8.0	8.2	8.2	0.96

1/ Includes the area of Yungas from 1981 onwards.
2/ The NIS includes the Northern, Central and Southern Systems.
3/ The Oriental System is integrated to the NIS.
4/ Diversity factor is lower after 1985 due to the connection of the large Oriental System.

Source: ENDE-1981 - Figures for 1980 and 1981 revised according to the Draft Report "Plan Nacional de Electrification" where indicated by an asterics.

Bolivia: Statistical Data and Forecast for the Power Sector
Gross Energy Generation (GWh)

Year	Northern System	Central System	Southern System	Oriental System	Other Areas	Total Country	NIS Generation
Actual							
1975	322.2	348.7	114.7	79.0	192.4	1057.0	
1976	331.0	381.8	127.8	96.7	194.7	1132.0	
1977	352.8	437.9	142.7	119.0	207.3	1259.7	
1978	375.3	463.8	144.8	142.7	227.2	1353.8	
1979	403.6	489.3	139.4	165.6	234.8	1432.7	
1980	426.9	541.2	159.4	202.7	236.1	1566.3	
1975-80 Growth %	5.8	9.2	6.8	20.7	4.2	8.2	
1981	441.7 1/	579.6	180.3	234.8	240.9	1677.3	1201.6 2/
1980-81 Growth %	3.5	7.1	13.1	15.8	2.0	7.1	
Forecast							
1982	523.9	634.9	174.7	269.0	262.3	1864.8	1333.5
1983	556.1	695.7	202.8	313.3	274.1	2042.0	1454.6
1984	590.9	706.4	225.6	364.6	288.9	2176.4	1522.9
1985	627.5	753.2	245.7	424.4	311.9	2362.7	2050.8 3/
1980-85 Growth %	6.6	7.8	10.2	15.9	4.9	8.6	9.1
1986	665.2	817.6	267.1	472.5	386.5	2608.9	2222.4
1987	705.1	883.4	290.5	524.6	403.4	2807.0	2403.6
1988	747.4	953.5	315.7	582.2	421.7	3020.5	2598.8
1989	792.2	1028.6	343.4	46.3	440.0	3250.5	2810.5
1990	839.7	1108.8	373.4	717.4	459.0	3498.6	3039.3
1985-90 Growth %	6.0	8.1	8.7	11.1	8.0	8.2	8.2

1/ Includes the area of Yungas.
2/ The NIS includes the Northern, Central and Southern Systems.
3/ The Oriental System is integrated to the NIS.

Source: ENDE 1981 - Figures for 1980 and 1981 revised according to the Draft Report "Plan Nacional de Electrificacion."

Bolivia: Revised Projection of Electric Power Demand (ENDE)
Gross Energy Generation (GWh)

	1982	1983	1984	1985	1986	1987	1988	1989	1990
Total Bolivia									
Demand (GWh)	1764.8	1855.5	1951.2	2052.8	2184.4	2325.4	2476.3	2638.1	2811.2
Total Integrated Systems									
Demand (GWh)	1519.1	1604.8	1695.5	1792.0	1917.1	2051.4	2195.4	2350.2	2516.1
Peak Demand (MW)*	293.9	310.5	328.1	346.7	370.9	396.9	424.8	454.7	486.8
Central System									
Demand (GWh)	608.0	637.8	669.0	701.8	749.5	800.5	854.9	913.1	975.1
Peak Demand (MW)	106.8	112.0	117.5	123.3	131.6	140.6	150.1	160.4	171.3
Southern System									
Demand (GWh)	192.6	205.7	219.6	234.6	248.7	263.6	279.4	296.2	313.9
Peak Demand (MW)	34.4	36.7	39.2	41.8	44.4	47.0	49.8	52.8	56.0
Northern System									
Demand (GWh)	462.6	482.3	502.8	524.2	554.4	586.3	620.0	655.7	693.4
Peak Demand (MW)	105.4	109.9	114.4	119.2	126.0	133.2	140.7	148.6	156.9
Oriental System									
Demand (GWh)	255.9	279.0	304.1	331.4	854.5	401.0	441.1	485.2	533.7
Peak Demand (MW)	55.8	60.8	66.3	72.3	79.5	87.4	96.2	105.8	116.4
Other Areas									
Demand (GWh)	245.7	250.7	255.7	260.8	267.3	274.0	280.9	287.9	295.1
Peak Demand (MW)	65.5	65.8	68.1	69.5	71.2	73.0	74.9	76.7	78.6

* Diversity Factor = 0.98

Source: Draft Report "National Electrification Plan" - February 1983

Bolivia: Power Generation Alternatives

Cost Study

Data	Unit	Sakahuaya Hydro Plant	Cochabamba Combined Cycle	Santa Cruz Combined Cycle	Santa Cruz Gas Turbine
Installed Capacity	MW	2x36 = 72 1/	2x45+1x45 2/	2x36+1x36 3/	4x24 = 96 4/
Effective Capacity	MW	72	72	72	72
Net Generation	GWh	360	360	360	360
Thermal Efficiency	Kcal/Kwh	-	2200	2200	3050
Gas Consumption	CF/Kwh	-	8.35	8.35	11.58
Investment Cost Total (1982)	US$ Million	150	74	59	29
Plant		130	74	59	29
Transmission		20	-	-	-
Investment Cost Unit (1982)	US$/KW				
Per KW Installed		2083	550	550	300
Operating Costs: Total	US¢/Kwh	0.15	0.21	0.18	0.17
Fixed	US$/KW Installed	7.0	4.0	4.0	4.0
	US¢/Kwh	0.14	0.15	0.12	0.11
Variable (Non-Fuel)	US¢/Kwh	0.01	0.06	0.06	0.06
Economic Life	Years	40	15	15	15
Calculation					
Capital Cost					
12% discount rate	¢/Kwh	5.05	3.02	2.41	1.18
14% " "		5.86	3.35	2.67	1.31
16% " "		6.68	3.69	2.94	1.44
Non-Gas Generating Costs	¢/Kwh				
12% Capital Costs		5.20	3.23	2.59	1.35
14% " "		6.01	3.56	2.85	1.48
16% " "		6.83	3.90	3.12	1.61
Break Even Gas Price	$/MCF				
12% Capital Cost		-	2.36	3.13	3.33
14% " "		-	2.93	3.78	3.91
16% " "		-	3.51	4.44	4.51

1/ Assuming a 100% availability of capacity in a hydro-power plant.
2/ The availability in a combined cycle equipment is assumed to be 66% (one of the two turbines is not operating). Due to the altitude of Cochabamba, the turbines have an additional de-rating of 20%.
3/ For Santa Cruz, the de-rating does not apply.
4/ Gas turbines are assumed to be available 75%, (one out of four turbines is not working).

Source: Mission Estimate

ANNEX 1.31

Bolivia: Investment Requirements - Energy Sector - Hydrocarbons
(in 1980 prices)

Hydrocarbons	Physical Work	YPFB 1981 - 1985 (1980 prices) (Million US$)	1982-1986 Without Pipeline to Brazil	1982-1986 With Pipeline to Brazil	1986-1990 Without Pipeline to Brazil	1986-1990 With Pipeline to Brazil
EXPLORATION						
Prospection						
Geology	3,560 kms	3	-	-	3	3
Seismic	2,155 kms	12	-	-	12	12
Shales		2	-	-	2	2
Seismic-Stratigraphic a/	3,400 kms	13	-	-	13	13
Boomerang		5	-	5	-	-
Drilling						
Stratigraphic wells b/	28	43	-	-	21	43
Structural c/	41	144	-	-	72	144
Structural-step-out	15	54	-	-	54	54
Boomerang	12	20	-	20		
Development						
Vuelta Grande:						
Wells	5	18	18	18	-	-
Gas Recycling Plant		24	24	24	-	-
LPG Plant		4	4	4	-	-
Espino						
Wells	4	15	-	-	15	15
Gas Plant		7	-	-	7	7
New Fields						
Wells	43	182	-	-	91	182
Field Equipment	7	33	-	-	20	33
Boomerang						
Gas Fields: Wells	17	84	-	84	-	-
Production Wells (Caranda, Colpa, Rio Grande, La Pena)	17	40	40	40	-	-
Gas Processing Plant Santa Rosa	(360 MMPCD)	40	-	40	-	-
Gas Compression Colpa		3	-	-	3	3
Secondary Recovery Camiri (Water Injection)		8	-	-	8	8
Secondary Recovery Monteagudo (Water Injection)		5	5	5	-	-
Tertiary Recovery La Pena (LPG Injection)		2	2	2	-	-
Others						
Drilling Equipment	4	45	-	-	25	45
Production Facilities		5	5	5	-	-
Processing						
Ammonia-Urea		76	-	-	-	
Av-gas 100-130 Santa Cruz		0.3	0.3	0.3	-	-
Thermostable residues		3	-	-	-	3
Transport						
Pipeline to Brazil		389	-	389	-	-
Santa Cruz-Altiplano d/		76	27	27	-	112
Extension Monteagudo-Sucre-Phase II (cost 21.2)		13.4	13.4	13.4	-	-
Yacuiba-Tarija		30	-	-	-	-
Gas Gathering Boomerang		49	-	49	-	-
Porvenir-Nancardines		1	1	1	-	-
Lateral gas lines:						
Porvenir-Vuelta Grande		3	3	3	-	-
Vuelta Grande-Taguipa		1	1	1	-	-
Villa Montes-Chorety		2.0	2	2	-	-
Gatherline Lines-New Fields		7	-	-	3	7
MARKETING-DISTRIBUTION						
Natural Gas		14	14	14	-	-
Distribution Networks: in La Paz, Santa Cruz, Sucre, Potosi		57	-	-	57	57
Service Stations		6	6	6	-	-
Terminal La Paz		15	15	15	-	-
Total YPFB		1554	181	768	406	743

a/ The most interesting area is the Rio Grande North; IDB has in principle (1982) agreed to finance the seismic exploration of this portion. The other favorable area is Madre de Dios, for which two service contracts have have been negotiated.
b/ IDB has also agreed to finance the drilling of 8 wells in the Rio Grande North area.
c/ Of these, 31 wells have the objective of finding new fields and 10 are to find deeper structures.
d/ Figure for Altiplano pipeline was revised according to IDB project description.

ANNEX 1.32

Bolivia: YPFB: Revised Operational Income - 1982
(million $b)

	Original Budget	YPFB's Feb. 1982 Revision	Rate of Change	Revision Mid-1982 1/	Rate of Change Respect Budget
Sales Revenue	18,095	28,749	59	28,749	59
Internal Market	7,956	11,111	39	-	-
General Oil Producers	6,366	7,932	25	-	-
Aviation Products	817	2,004	145	-	-
Lube Oils	529	805	52	-	-
Others	243	370	53	-	-
Exports	9,870	17,368	76	36,081	266
Via Arica	496	873			
Gas to Argentina	9,229	16,240			
LPG to Brazil	145	254			
Other Revenue	270	270	-	270	-
Operational Expenditures	13,546	20,594	59	31,841	135
Operational Budget 2/	3,454	5,119	48	4,900	142
Other Expenditures 3/	2,707	4,684	73	13,264	390
Taxes	6,305	8,925	42	8,925	42
Interests and Commissions	1,080	1,866	73	4,752	340
Balance	4,550	8,155		33,259	
Balance (US$) 4/	186	185		371	

1/ Mission Revision based on double exchange rate: $b 44/US$ for 40% of revenue and $b 120/US$ for 60% of revenue. All foreign exchange expenditures at $b 120/US$.

2/ Assumes 20% foreign component - 80% national escalated at 80% inflation.

3/ Assumes 100% foreign component.

4/ Budget at 24.51; February 1982 at 44; and Mission revision at $b 89.6/US$.

ANNEX 1.33

ENDE: Investment Program 1981-87
(in million US$-1980 prices)

ONGOING WORKS:			60.5
(a)	Interconnected System		
	Generation:		
	Sta. Isabel Enlargement	0.6	
	Corani-Dam Enlargement	44.9	
	Potosi-Gas Turbine	8.3	
	Transmission	4.2	
(b)	Other Systems	2.5	
FUTURE WORKS:			459.6
(a)	Interconnected System		
	Generation:		371.9
	Sakahuaya and T/L - Hydro	89.9	
	Icla and T/L - Hydro	167.0	
	Palillada and T/L - Hydro	78.1	
	Sta. Isabel - 4th Unit - Hydro	2.4	
	Santa Cruz - 5th Gas Turbine	7.2	
	Pilaya and T/L - Hydro	27.3	
	Transmission		
	Central-Oriental Interconnection	42.7	42.7
(b)	Other Systems		
	San Jacinto - Hydro	12.3	45.0
	Trinidad - Thermal	2.6	
	Cachuela - Esperanza	14.0	
	Transmission - Subtransmission	14.1	
	Other Small Work	2.0	
	TOTAL INVESTMENT		520.1

Source: ENDE V Power Project Report - Annex 4.4

Retail Prices of Major Petroleum Products, La Paz, 1975-82
($b/liter)

		Prior to Nov. '75	Dec. '75- Nov. '79	Dec. '79- Dec. '80	Since Jan. 81	Since Feb. 5, 1982	Since Nov. 6, 1982
Gasoline - super	1.10	3.50	5.00	(	(	20.8	25
- premium	n.a.	5.00	6.00	7.00	10.00	10.00	35
Kerosene - domestic		0.25	0.30	1.00	(4.00	5.0	8
- industrial use		0.40	0.50	4.00	(		
Diesel - public	(0.55	1.30	4.00	(6.00	8.00	10.4	23
- power generation		(		2.50	(		
Fuel oil	0.30	1.10	4.00	5.50	7.50	5.7	22
LPG a/ - domestic use		(	(	2.00	(	3.50	5
- industrial use		(--	(0.50	(1.30	(3.00	4.50	14
- automotive use		(	(	(	(	5.00	15
Natural gas (per MCF)		--	20.00	20.00	25.00	45.00	

a/ $b/kg

Source: YPFB

Bolivia: Boomerang Area - Exploration and Development Cost Estimate
(in 1980 constant prices - million US$)

	1981	1982	1983	1984	1985	1986-1993	1994	1995	1996	1997	1998	1999	2000
INVESTMENTS													
EXPLORATION													
Seismic	3.3	2.2											
Drilling	18.3	1.9											
Overheads	2.2	0.4											
DEVELOPMENT													
Drilling			15.1	28.8	40.0								
Gas Plant				20.0	20.0								
Gathering Pipes				5.0	5.0								
Overheads			1.5	5.3	6.5								
TRANSPORT													
To Colpa			5.0		17.5								
Colpa a Mineros					57.1								
TOTAL	23.8	4.5	16.6	64.1	146.1								
Net Present Value (14%)	170.3												
Net Present Value (12%)	179.5												
GAS PRODUCTION (10^6CFD)													
Enconada						30	10	-	-	-	-	-	-
Yapacani						100	100	90	50	20	10	0	
Santa Rosa						180	180	180	160	140	140	130	130
TOTAL GAS PRODUCTION (10^6CFD)						113.2	106	99	77	58	55	47	47
Net Present Value (14%)	378 x 10^6CF												
Net Present Value (12%)	445 x 10^9CF												

Average Cost: (14%). US$0.45/MCF
(12%). US$0.40/MCF

Bolivia: Transport Cost Monteagudo-Sucre Extension to Cochabamba and La Paz

	Investment 1/ (MMUS$			Operating	Gas	Total	Gas Transport 4/	
	Phase I	Phase II	Phase III	Maintenance 2/	Consumption 3/	Outflow	MMCFD	10^6CF/y
1981	13.2	10.0			0.2	23.4	3.6	1314
1982		11.2	4.8	0.7	0.2	16.9	3.6	1314
1983			15.0	1.17	0.4	16.57	22.1	8067
1984				1.62	0.4	2.02	24.3	8869
1985				1.62	0.4	2.02	25.7	9380
1986				1.62	0.4	2.02	25.7	9380
1987				1.62	0.4	2.02	25.7	9380
1988				1.62	0.4	2.02	25.7	9380
1989				1.62	0.4	2.02	25.7	9380
1990				1.62	0.4	2.02	25.7	9380
1991				1.62	0.4	2.02	25.7	9380
1992				1.62	0.4	2.02	25.7	9380
1993				1.62	0.4	2.02	25.7	9380
1994				1.62	0.4	2.02	25.7	9380
1995				1.62	0.4	2.02	25.7	9380
1996				1.62	0.4	2.02	25.7	9380
1997				1.62	0.4	2.02	25.7	9380
1998				1.62	0.4	2.02	25.7	9380
1999				1.62	0.4	2.02	25.7	9380
2000				1.62	0.4	2.02	25.7	9380
2001				1.62	0.4	2.02	25.7	9380
Total (at 14% discount rate)							60.88	54,325.8

Average Transport Cost: US $1.12/MCF

1/ Phase I (1980 US$) refers to investments made in late 1980. Phase II (1982 US$) refers to extension to Cochabamba and Phase III to Cochabamba-La Paz.
2/ 3% of accumulated investment in previous year.
3/ Priced at US$11 MCF - Consumption as estimated by YPFB for compression stations is 1.1 MMCFD.
4/ Supply limited to 25.7 MMCFD - Total connections in 1983 are 11 new customers in La Paz, Oruro and Cochabamba.

ANNEX 1.37

Bolivia: Transport Cost -Altiplano Pipeline - Santa Cruz-Cochabamba and La Paz
Baseline Demand Scenario

	Investment 1/ (1000 US$)	Operation & Maintenance	Gas Consumption 10^6CF	Costs 10^6US$	Gas Sales MMCFD	Gas Sales MMCFY	
1982	968			0.97	-	-	
1983	19,547			19.55	-	-	
1984	53,754			53.75	-	-	
1985	26,054	750	27	26.83	6.0	2,190	
1986	-	3000	137	3.14	24.3 2/	8,870	
1987	-	3000	164	3.16	25.3	9,234	
1988	-	3000	186	3.19	26.3	9,600	
1989	-	3000	220	3.22	27.3	9,964	
1990	-	3000	258	3.26	28.3 3/	10,330	
1991	-	3000	275	3.28	29.5	10,768	
1992	752	3000	346	4.10	30.8	11,242	
1993	-	3028	369	3.40	32.1	11,717	
1994	4,176	3028	542	7.75	33.5	12,227	
1995	-	3175	590	3.77	35.0	12,775	
1996	7,380	3175	660	11.22	36.4	13,286	
1997	6,864	3433	707	11.00	38.8	14,162	
1998	16,696	3673	806	21.18	41.3	15,075	
1999	-	3904	905	4.81	44.0	16,060	
2000	5,124	3904	1015	10.04	47.0	17,155	
2001	-	3904	1140	5.04	49.8	18,177	
2002	6,864	4084	1280	12.23	52.6	19,200	
At 14% Discount Rate				98.11		49.699	$1.97/MCF

1/ As estimated by YPFB - IDB includes technical costs only.
2/ Main 1981 clients without increase and La Paica and ENDE in Potosi.
3/ 80% of 1990 total demand for the region. For the 1990's escalation is based on GDC's incremental values, base case.

ANNEX 1.38

BOLIVIA: Mean Annual Wind Speed

Department	Station	Wind Speed (Km/hr)
La Paz	El Alto	6.9
Cochabamba	Cochabamba	3.5
	Todos Santos	4.1
Santa Cruz	Camiri	5.2
	Puerto Suarez	7.4
	Concepcion	13.9
	Robore	10.8
	Santa Cruz	19.2
	San Jose	12.2
	San Ignacio de Velasco	8.9
Beni	Riberalta	6.3
	Santa Ana	11.1
	San Ignacio de Moxos	8.9
	Guayaramerin	5.6
	Trinidad	13.0
	Magdalena	8.5
	Rurrenabaque	4.1
	San Borja	7.6
Pando	Cobija	4.8
Oruro	Oruro	9.6
Chuquisaca	Sucre	6.3
Potosi	Uyuni	6.1
Tarija	Tarija	8.1
	Yacuiba	9.8

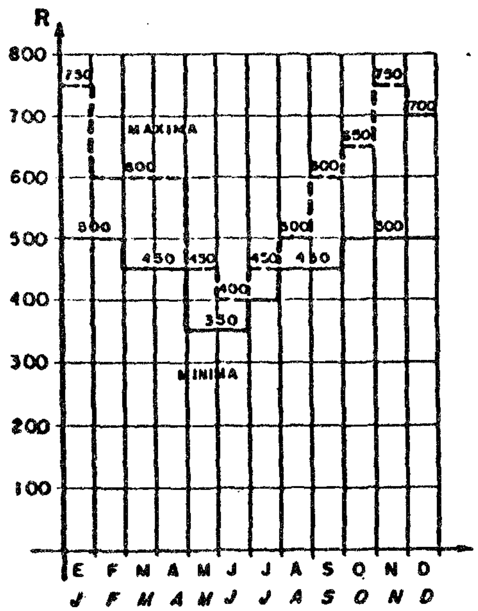
Source: Instituto de Investigacion Fisicas.

VALORES DE RADIACION GLOBAL

GLOBAL RADIATION VALUES

R en cal/cm²/day

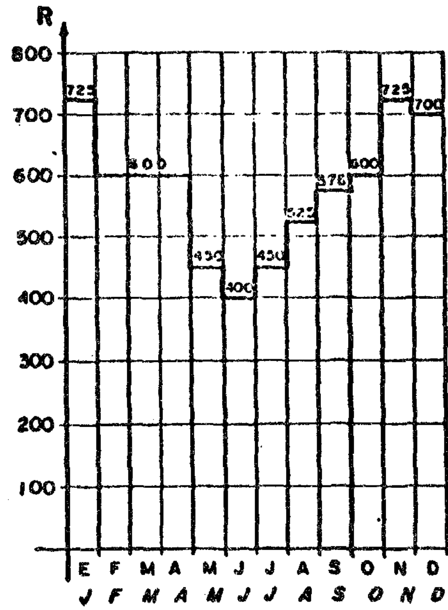
1.- BOLIVIA



2.- ZONAS CLIMATICAS

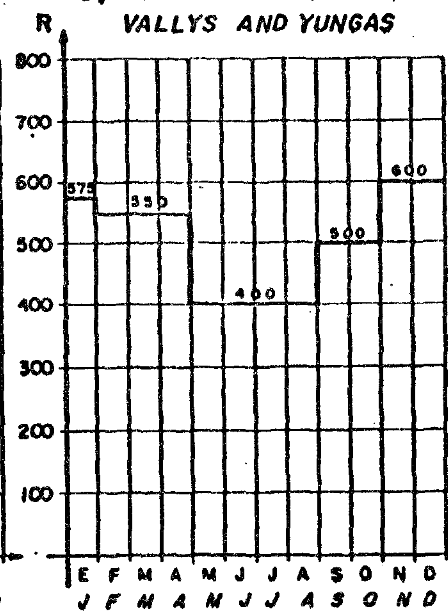
CLIMATIC ZONES

a) ALTIPLANO



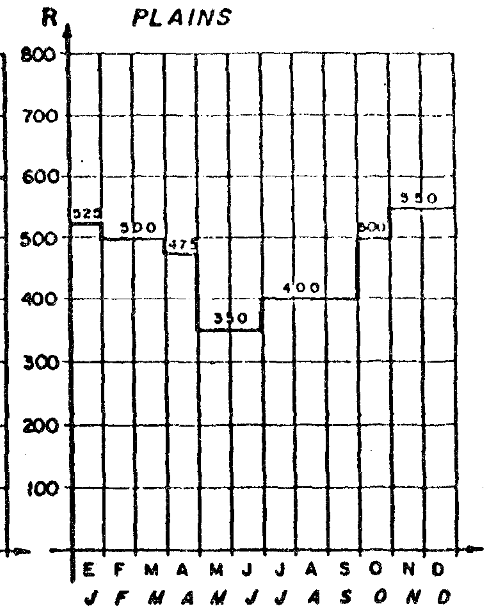
b) LOS VALLES Y YUNGAS

VALLYS AND YUNGAS



c) LLANOS

PLAINS



SUGAR PRODUCTION, RESIDUES, AND ENERGY CONSUMPTION IN SUGAR MILLS 1/

Sugar Mills Per Province	1980: Sugarcane Milled (for sugar) T	1980: Sugar Production T	1980: Area Planted HA	1980: Yield Sugarcane T/HA	Fuel Consumed at the Sugar Mills in 1980: Bagasse T 10^3	Natural Gas Cubic Feet	Oil T	Firewood T
Guabira	707,642	60,452			260		1,454	7,761
La Belgica	449,931	38,460			157	332,706,740	590	
San Aurelio	305,913	27,653			103	244,018,000		
Unagro	472,766	41,143			153		435	2,170
Santa Cruz	1,936,252	167,708	55,742	35	677	576,724,740	2,479	9,931
Stephen Leigh	228,305	26,358						
Moto Mendez	414,949	48,056						
Tarija Bermejo	643,254	74,414	8,814	73	173		6,171	42

1/ La Industria Azucarera Boliviana, 1980 - Comision Nacional de Estudio de la Cana y del Azucar.

ANNEX 1.41

BOLIVIA: ALCOHOL PRODUCTION FROM SUGARCANE - 1980

<table>
<tr><th rowspan="2">Sugar Mills (Distilleries)</th><th rowspan="2">Molasses T</th><th colspan="2">Alcohol Production 1,000 ltrs.</th></tr>
<tr><th>Absolute Alcohol 96 (Buen Gusto)</th><th>Alcohol 95 (Mal Gusto)</th></tr>
<tr><td>Guabira</td><td>33,149</td><td>7,659</td><td>897</td></tr>
<tr><td>La Belgica</td><td>18,297</td><td>5,565</td><td>821</td></tr>
<tr><td>San Aurelio</td><td>16,217</td><td>3,715</td><td>546</td></tr>
<tr><td>Unagro</td><td>21,050</td><td>3,866</td><td>606</td></tr>
<tr><td>Stephen Leigh</td><td>8,512</td><td rowspan="2">1,920</td><td rowspan="2">259</td></tr>
<tr><td>Moto Mendez</td><td>15,923</td></tr>
<tr><td></td><td>113,148</td><td>22,725</td><td>3,129</td></tr>
</table>

Source: La Industria Azucarera Boliviana, 1980 - Comision Nacional de Estudio dela Cana y del Azucar.

Brief of Geology

1. Marine sediments began to be deposited over the entire area of present day Bolivia, except for the far northeastern portion during the Ordovician period. And, the Ordovician seas may have covered even the present day Brazilian Shield in Bolivia, with the sediments having been removed by later erosion.

2. Marine deposition continued, apparently without a pause, through the Silurian and Devonian periods so that at one time more than 15,000 feet of marine sandstones and shales were present over the country, again except for the far northeastern portion. Here again, a much greater thickness may have been present, as we know that erosion, which took place during later geologic periods, removed much of this section and redeposited it in the younger basins which continued to develop to the west.

3. The Ordovician section is not very well known, as it does not outcrop in the oil producing areas and has been seen in only a few exploratory wells, which are both updip from the producing area and near to the Brazilian Shield. It is essentially a quartzite and quartzitic sand with some dark grey shale. It would appear to have little chance of being hydrocarbon productive as the porosity is low and little if any source material is present from which hydrocarbons could have been generated.

4. The Silurian section is composed of sandstones and shales. Also with the section being shalier as one moves farther away from the Brazilian Shield. Although the rocks of this period are mostly shale, the Sara sandstone in the Palometas NW and Santa Rosa fields are thought to be of this age. In the former field, the Sara contains 54 meters or net pay with 10% porosity and it tested 8.5 MMCFDG with 30 b/dc (barrels per day of condensate) at a depth of 2600 meters. In the latter, it had over 65 meters of net pay with 9% porosity and tested 7.7 MMCFDG with 15 b/dc. A thick section of Sara pay sand has been reported in the Yapacani X5 development well so this section must be considered an important pay zone, particularly in the Boomerang Hills.

5. The Devonian section, which is also a clastic section, is considered to be the source of most, if not all, the hydrocarbons in the country. It is mostly a shale section, many thousands of feet thick, with varying amounts of sandstone. The shale is dark and has a high organic carbon content. Most of the many oil seeps along the Subandino Zone of the country originate either from these sands or from faults which cut this Devonian section.

6. Sandstones within the Devonian is the reservoir at Camiri, where 46.8 million barrels of 55 API oil have been produced since discovery in 1927 and where 880 b/d is still being produced.

7. At the end of Devonian time a gentle uplift occurred, which formed an unconformity over the entire country. The Carboniferous age deposition, which followed and extended up into the Permian period, was confined to a smaller area and was no longer of marine origin, particularly in the southern half of the country. The Brazilian Shield remained a positive element and supplied sediments, part of which were undoubtedly eroded Ordovician to Devonian rocks. This deposition took place on a flood plain near the Shield and in lakes farther west. Glacial deposits are also thought to be present. Because of the general continental origin of these sediments the hydrocarbons produced from this section (and 70% of the country's reserves are in these rocks) are thought to have originated in the underlying Devonian shales.

8. Rocks of the Permo-Carboniferous are confined to the Subandino and Chaco Zones in the southern half of the country, and if they extended farther west during deposition, subsequent latter uplift and erosion have removed them. In the northwestern Subandino Zone there is little or no evidence of the rocks of this age. This lack of section may be due to erosion but more likely it is due to non-deposition as the Ichilo Fault Zone was probably activated at the end of the Devonian time. This action moved the Brazilian Shield much farther to the west than it appears to be now, as evident by the lack of sedimentary rocks of all ages, except for the Tertiary over much of the Beni.

9. Permo-Carboniferous rocks in northwest Bolivia around Lake Titicaca and also in southeast Peru have a much different depositional history and appear to have no bearing on the presently producing areas of the country. However, this northwestern area may have hydrocarbon potential, but the degree cannot be ascertained at present.

10. Because of the nature of deposition the sandstone reservoir beds are erratic in development and lenticular in nature. However porosites are good, usually 15% or better, and permeabilities are also good. Because of the lenticular nature of the sands, it is difficult to estimate reserves accurately with only a well or two on a structure.

11. A slight unconformity developed at the end of the Permo-Carboniferous deposition, but it appears to be of no importance as far as oil accumulation is concerned.

12. Except for a short marine transgression in early Cretaceous time, as evidenced by some calcerous content in rocks of that age, the remaining Cretaceous rocks, as well as the overlying Tertiary section,

are of continental origin. These are usually typical redbeds with mostly shale and poorly developed sandstone. However, some clean, generally thin sandstones of reservoir quality do develop and are some times productive. An example would be the Tacuru (L. Tertiary) in the Vuelta Grande X1 well where four sands, totally 14.5 meters, tested 6.7 MMCFDG and 323 b/dc through a 28/64" choke.

13. Although minor structural development may have occurred in this area prior to the Andean Orogeny of Late Tertiary age, any evidence of it has been obliterated by the violent movements of said orogeny. In addition, any hydrocarbons that had been trapped in pre-Andean traps have probably migrated into the much larger, present-day traps and, sorry to say, much of the hydrocarbons have been lost through seepage from these traps.

14. Broadly speaking, there are two structural zones that have importance from a hydrocarbon standpoint. The first is the Subandino Foothills Zone where the structure is aligned with the Andean Mountain Range and where there is usually a surface expression of the structure so that surface mapping of the structure is possible. It was in the southern portion of this area that Jersey Standard geologists began their mapping in the early 1920's and where Camiri Field, which is one of the five largest fields in the country, was discovered in 1927. As the structures within this Subandino Foothills Zone are very complex structurally and as they are often thrust faulted, the subsurface high (at the hydrocarbon objective depth) does not always coincide with the surface high. This fact has caused many dry holes to be drilled and often three or four exploratory wells must be drilled on structures to either prove it to be productive or to condemn it completely.

15. The Chaco Plains, immediately to the east of the Subandino Foothills, have structures of much the same type as those in the foothills, in that they are elongate, north-south anticlines which are usually thrust faulted to some degree. But, they differ in that most have a thick section of Tertiary rocks covering them, so that they have few if any outcrops that can be mapped by geologists, and structures usually have gentler dips and less complex faulting.

16. Much seismic work was carried out in this area and also in the Santa Cruz portion of the Chaco in the late 1950's and first half of the 1960's. The work in the southern part was unsuccessful, probably due to the complicated structural development, but it was highly successful in the Santa Cruz area where the structures are broader and much simpler in structural style. Of the 28 exploratory wells drilled in the Santa Cruz area, 12 discovered hydrocarbons and eight have enough reserves to be producible. It appears that with the better seismic techniques now available, the entire Chaco Plains, to the south of Santa Cruz, will

go through another exploration phase. Tesoro and Oxy have already begun this phase.

17. The eastern flank of the Chaco Plains in the Izozog Swamp area, some 250 kilometers south southwest of Santa Cruz, was explored for stratigraphic traps back in 1959 to 1961 when Gulf drilled 12 widely spaced stratigraphic tests. This effort was unsuccessful, but possible stratigraphic traps must be considered all along the east flank of this basin. YPFB personnel have made a study of the area to the north and northeast of Santa Cruz with stratigraphic trap exploration in mind. As this is a highly speculative venture, it should be undertaken as a last resort.

18. The remaining geologic provinces have little to no hydrocarbon potential. The Brazilian Shield has basement outcrops and these basements rocks extend far westward into the Beni under a thin veneer of Tertiary and possibly Cretaceous rocks, as evident from an exploratory well drilled near 14°S and 66°W, which entered basement rock at about 2600 feet. The far northwestward portion of the Subandino Foothills Zone have a number of anticlines typical of this zone (see map) which are worthy of testing, and the adjacent Madre de Dios is worthy of additional exploration.

19. The large Eastern Andean Range is composed of Devonian through Ordovician shales and sandstones which are tightly folded, faulted and metamorphosed to some degree. Granite intrusions are present along the west portion of this geologic province. It is considered to have no oil potential.

20. The Altiplano geologic province is a large graben lying between the Eastern and Western ranges of the Andes. After the drilling of five exploration wells and the recording of about five thousand kilometers of seismic data, this graben is known to contain upwards of 10,000 feet of hard, silicified Tertiary sandstones and shales, which have no hydrocarbon potential. There may be areas within this vast graben where Cretaceous rocks may be buried and may have hydrocarbon potential and in the far northern portion some Permo-Carboniferous rocks may be present in the subsurface. However, based on the information obtained to date, this area must be considered to have very poor to non-existent hydrocarbon potential. However, commercial oil deposits have been formed in basins located in Northern Argentina (CAIMANCITO) and in southern Peru (PIRIN).

Exploration History and Anticipated Exploration

21. Hydrocarbon exploration began in Bolivia in the early 1920's when Jersey Standard took a large concession in the Subandino Foothills from about the area of Camiri Field to the Argentine border. This was a continuation of their exploration effort in the same geologic province in Argentina.

22. Their effort consisted entirely of field mapping and exploration drilling. The exact number of exploratory wells that Jersey drilled is not known, but it must have been at least ten, as they discovered a number of small fields after the discovery of the rather large (for Bolivia) Camiri Field in 1927.

23. Jersey continued sporadic exploration in the country during the early 1930's but large discoveries in Venezuela forced their attention there and then political complications, brought on by the Bolivia-Paraguay Chaco War, finally lead to the nationalization of the Jersey concession in 1938.

24. Complete stagnation of the oil industry took place for the next 15 years. The following principal events can be noted:

(a) Camiri field discovered 1927
(b) Jersey Standard nationalized 1938
(c) Glenn McCarthy granted concession 1953
(d) Gulf Oil granted a concession 1956
(e) First exploratory well in Santa Cruz Area 1960
(f) Pipeline to Pacific completed 1965
(g) Gulf Oil nationalized 1968
(h) Contracts again led to private companies 1973.

25. As soon as Gulf was granted a concession in 1956, many other private companies entered Bolivia and exploration work began in earnest. However, after the expenditure of much money on seismic and gravity programs, as well as a number of exploration wells, all companies were unsuccessful with the exception of Gulf, who had made a number of discoveries in the Santa Cruz area. These had all been found by using seismic methods and not by using surface geologic studies as had Jersey Standards in their 1920 and 1930 exploration programs.

26. Economic conditions in the world oil markets in the late 1950's and early 1960's were not good, so, as the private companies completed their unsuccessful exploration programs in Bolivia, they released their concessions and withdrew from the country. And, as shortly thereafter, areas with greater potential, such as the North Sea, Iran, Australia and Indonesia, became available for exploration, the private companies lost interest in Bolivia.

27. Gulf continued with their exploration effort at a rather strong pace right up to their being nationalized. However, their early successes at Rio Grande, Colpa, and Caranda in 1960 and 961 were not repeated and reserves were added at a miniscule rate, although a large number of exploration wells and a number of discoveries (all very small) were made.

28. The large increase in gas reserves in 1973 was due to further exploration by YPFB in the Boomerang Hills area. A number of discoveries had been made by Gulf in this area, but as they were dry gas and there was no market for such gas, Gulf did not develop the area.

29. In 1973, the Bolivian Government again opened much of the country for exploration by private companies. Thousands of miles of seismic data was recorded, much of it in the Beni Plains and Altiplano, both of which had been explored only slightly before this effort was made. However, YPFB held in reserve for themselves almost all of the Subandino Foothills Zone from Santa Cruz to the Argentine border and did hold all the Chaco Plains, Boomerang Hills and Santa Cruz area, which were immediately to the east of the Subandino Foothills.

30. On the original exploration contract areas no private companies were successful except for Occidental, which discovered the Tita Field east of Santa Cruz.

31. In 1976, both Occidental and Tesoro obtained contract areas in the Chaco Plains area on portions of that area that had been originally held in reserve by YPFB. It is on these later contract areas that they have made the Porvenir and La Vertiente discoveries, respectively.

32. It would appear that this plain area from Santa Cruz to the Argentine border has fair potential for more gas discoveries, even though many of the structures have already been tested by one or more exploratory wells. This assessment is based on the fact that better seismic techniques have made it possible to map these complicated structures more accurately. Many times it had been found that the original exploration wells were not properly located on the subsurface high at the depth of the objective horizon.

33. The Southern Subandino Foothills, which incudes the area within the foothills from about Camiri southward to Argentina has been fairly well explored and no large discoveries are anticipated. The Santa Cruz Subandino Foothills is the area to the north of Camiri and it continues to the change of direction of this zone to the northwest. This area deserves additional exploratory drilling, but the possibility of finding large fields is low.

34. The Cochabamba Foothills is that area immediately to the northeast of Cochabamba. The potential of this area, after much seismic work and the drilling of five dry exploratory wells, is very poor.

35. The Santa Cruz area, lying between Caranda and Colpa Fields on the north and the El Dorado structure on the south, has been the most prolific producing area in the country. However, it appears to be

almost completely explored so no great increase in reserves is expected. The Boomerang Hills, a dry gas province to the north of Santa Cruz where wetter gas is produced, appears to be less explored and has a greater potential for an increase in reserves.

36. Stratigraphic traps may be present to the north and northeast of Santa Cruz as the entire geologic section thins from both less deposition and erosion toward the Brazilian Shield. There is no way to evaluate the potential of this area, but the chances of such traps developing must be considered poor.

37. The Chaco Plains area, immediately to the east of the Subandino Foothills and extending from the Santa Cruz area to the Argentine border, has the greatest potential for new discoveries. Not only have better seismic techniques made it possible to more accurately delineate the structures in this area, many of which have already been tested by dry holes, but the most recent discoveries, which have found over one trillion cubic feet of gas and 85 million barrels of condensate, were made in this area. These two important facts have made this area the focal point for exploration and only the lack of a large market for gas will slow the exploration effort.

Bolivia: Ammonia-Urea: Investment Cost Indicators

	West Germany 1/	Qatar 2/	Thailand 3/	Bolivia 4/	Bolivia-Brazil 5/
Capacity (1000 tons/year)					
Ammonia	300	430	375	52.8	300
Urea	510	690	600	80	510
Investment (US$ million)					
Ammonia					
Battery Limits	70.8	na	182	na	119.2
Off-Sites	28.4	na	72	na	47.8
Total	99.2		254		167.0
Urea					
Battery Limits	31.0	na	120	na	52.2
Off-Sites	25.1	na	20	na	42.3
Total	56.1		140		94.5
Total Investments	155.3	412	394	93.5	261.5
Unit Investment (US$/ton/year Urea)	305	600		1170	510

1/ Standard Research Institute - 1981 Yearbook.

2/ Qatar Gas Utilization Study - World Bank - May 1981 (Qatar already produces urea--this is additional capacity)

3/ Davy McKee - Thailand Gas Development Plan.

4/ Bolivia: Haldor Topsoe - Preliminary Estimate 1980. Escalated at 10% for 1981.

5/ Mission estimate for a joint venture - plant located in Brazil.

Bolivia: Ammonia Urea Complex
Financial Analysis - Ammonia 52.8 MTY - Urea 80 MTY
(in 1981 US$ million)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production Volume (MTY) 1/																			
Ammonia					30	39	46	46	46	46	46	46	46	46	46	46	46	46	46
Urea					52	68	80	80	80	80	80	80	80	80	80	80	80	80	80
Sales Volume (MTY)																			
Export Urea					46.4	61.8	73.4	72.9	72.4	71.9	71.3	70.7	70.1	69.4	68.6	67.8	67.0	66.0	65.0
Domestic Urea					5.6	6.2	6.6	7.1	7.6	8.1	8.7	9.3	9.9	10.6	11.4	12.2	13.0	14.0	15.0
Prices (US$/ton)																			
Urea					213	222	232	243	254	265	269	273	277	281	285	290	294	298	303
REVENUES					11.1	15.1	18.6	19.4	20.3	21.2	21.5	21.8	22.2	22.5	22.8	23.2	23.5	23.8	24.2
Investments																			
Fixed Capital		20.6	45.0	27.9															(9.4)
Training				2.0															
Working Capital 3/					1.7	0.6	0.5												(2.8)
Operating Costs																			
Variable Costs 4/ (excluding gas)					7.7	7.9	8.0	8.2	8.3	8.5	8.7	8.9	9.0	9.2	9.4	9.6	9.8	10.0	10.2
Freight 5/					2.3	3.1	3.8	3.8	3.8	3.8	3.9	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
TOTAL EXPENDITURES		20.6	45.0	29.9	11.7	11.6	12.3	12.0	12.1	12.3	12.6	12.9	13.0	13.2	13.4	13.6	13.8	14.0	2.0
NET CASH FLOW		(20.6)	(45.0)	(29.9)	(0.6)	3.5	6.3	7.4	8.2	8.9	8.9	8.9	9.2	9.3	9.4	9.6	9.7	9.8	22.2
Gas Requirements: 23,927 (million cubic feet) 6/					1,077	1,400	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650	1,650
Net Present Value 10%	(36.67)																		

Net Value of Gas: (US$36.7 x 10^6)/23,927 x 10^6 MCF = (1,53 US$/MCF)

1/ Operations to start in 1985 at 65% capacity; 1986 at 85% and full capacity thereafter.
2/ IBRD projections in constant 1981 prices (Table 8.9) to 1990; thereafter, 1.5% increase per year.
3/ Working capital - 15% of revenues until full capacity is reached.
4/ Includes labor and supervision US$2.0 MM/Y; maintenance 3% of fixed capital; insurance 1.5% of fixed capital; other variable costs (catalysts, utilities) US$1.5MM. The total is US$7.7 million - escalated at 2% per year.
5/ Freight to Brazil estimated at US$25/ton - escalated 1.5% per year on exportable surplus. Domestic demand assumed to grow at 7% year.
6/ Gas requirements estimated as follows: Raw material 22.6 MCF/ton of ammonia; Fuel 13.3 MCF/ton ammonia; Total 35.9 MCF/ton ammonia.

Bolivia: Ammonia - Urea Complex
Financial Analysis: Ammonia - 300 MTY; Urea 510 MTY
(in 1981 US$ million)

	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Production Volume (1000 tons)																			
Ammonia 1/					195	255	300	300	300	300	300	300	300	300	300	300	300	300	300
Urea 1/					332	434	510	510	510	510	510	510	510	510	510	510	510	510	510
Sales Volume																			
Urea to Brazil					326.4	427.8	503.4	502.9	502.4	501.9	501.3	500.7	500.1	499.4	498.6	497.8	497.0	496.0	495.0
Urea to Bolivia 2/					5.6	6.2	6.6	7.1	7.6	8.1	8.7	9.3	9.9	10.6	11.4	12.2	13.0	14.0	15.0
Prices (US$/ton) 3/																			
Urea					213	222	232	243	254	265	269	273	277	281	285	290	294	298	303
REVENUES					70.7	96.3	118.3	123.9	129.5	135.2	137.2	139.2	141.3	143.3	145.4	147.9	149.9	152.0	154.5
Investment																			
Fixed Capital 4/		57.6	126.0	77.9															(26.2)
Training				5.0															
Working Capital 5/					10.6	3.8	3.3												(17.7)
Operating Costs																			
Variable Costs 6/																			
(excluding gas)					19.3	20.8	22.0	22.5	22.9	23.4	23.9	24.3	24.8	25.3	25.8	26.3	26.9	27.4	28.0
Gas Transport to Brazil 7/					13.8	18.0	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2
Urea Transport to Brazil 8/					0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.6	0.6	0.6	0.6	0.8	0.8	0.8	1.0
TOTAL EXPENDITURES		57.6	126.0	82.9	43.9	43.0	46.9	44.1	44.5	45.0	45.5	46.1	46.6	47.1	47.6	48.3	48.9	49.4	6.3
NET CASH FLOW		(57.6)	(126.0)	82.9)	26.8	53.3	71.4	79.8	85.0	90.2	91.7	93.1	94.7	96.2	97.8	99.6	101.0	102.6	148.2
Gas Requirements 9/ 156,165 (million cubic feet)					7,000	9,155	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770	10,770
Net Present Value (10% discount)	236.3																		

Net Value of Gas: US$236.3 x 10^6/156.2 x 10^3 MCF = US$ 1.51/MCF

1/ Production volume: 1985: 65% of capacity; 1986: 85%; 100% thereafter.
2/ Bolivia's consumption projected to increase at 7% per year.
3/ Prices: IBRD projection in constant prices to 1990. Thereafter, 1.5% increase per year.
4/ Investment in fixed capital estimated with a localization factor of 1.6. Salvage value of 10% at end of 15 years.
5/ Working capital 15% of revenues until full production capacity is reached.
6/ Operating costs: includes labor and supervision: US$4.00 MM/Y; maintenance 3% and insurance 1.5% of fixed capital. Other variable costs (utilities, catalysts and other input) at US$3.70/ton of urea and US$11.66/ton of ammonia). The total sums US$21.2 million escalated at 2% per year.
7/ Assumes that plan is built in Sao Paulo and that the average transport cost is US$1.97/MCF.
8/ Assumes that Bolivian requirements are supplied from Brazil, at a transport cost of US$50/ton escalated at 1.5% per year.
9/ Gas requirements calculated at 35.9 MCF/ton of ammonia. Includes feedstock and energy.

Bolivia: Methanol: Investment Cost Indicators

	West Germany 1/			Qatar 2/	Bolivia 3/	
Capacity (1000 tons/year)	160	320	640	693	160	320
Investments (US$ million)						
Battery Limits	40.7	64.3	108.2	na		
Off-Sites	17.1	28.4	49.9	na		
Total Fixed Capital	57.8	92.7	158.1	358.0	93	150
Unit Investment (US$/ton/year)	360	290	250	520	580	470

1/ Stanford Research Institute International. PEP Yearbook 1981.
2/ Qatar - Gas Utilization Study - World Bank 1981. Based on Saudi Arabian Case.
3/ Mission Estimate - Assuming localization factor of 1.6. Data compares with Case 3 - Table 12 of World Bank's Report on "Emerging Energy and Chemical Applications of Methanol: Opportunities for Developing Countries" - April 1982.

Bolivia: Methanol: Assumptions for Cost Calculations

Capacity (1000 tons/year)	320
Investment Cost (Million US$)	
Fixed Cost	150
Working Capital	8
Construction Period	over 4 years - 10%, 30%, 35%, 25%
Production Buildup	60%, 80%, 100%
Stream Days	330 days
Labor Costs (US$ million)	0.8
Overhead (US$ million)	0.7
Maintenance (% of Fixed Capital)	3%
Catalysts and Supplies	US$5 per ton
General, Administration and Marketing (% of Sales)	2%
Insurance and Other (% of Fixed Capital)	1%

Source: World Bank "Emerging Energy and Chemical Applications of Methanol: Opportunities for Developing Countries", April 1982.

Technical Assistance Requirements

Ministry of Energy and Hydrocarbons (MEH)

1. Consolidation of the energy planning unit and set-up of an Energy Data Bank.

2. Organizational study to strengthen DINE and DNH.

3. Review of the legal framework (laws and regulations) for contracting hydrocarbon prospects with private companies.

4. Design of an energy conservation policy: legal aspects, financial incentives and information campaign.

5. Urban transport study to enhance efficient energy use.

6. Organizational study of YPFB to improve coordination and efficiency of integrated operation. It should include the following aspects:

   (a) Analysis of the company's organizational structure, functions and objectives of each managerial and operational unit, evaluation of present and future staff requirements, and control systems.

   (b) Analysis of salary structure and development of a career development program.

   (c) Set-up of a management information system.

   (d) Introduction of modern analytical planning and optimization models, including refinery model and an investment model for scheduling development of oil and gas fields.

7. Fixed term productivity expert to induce cost saving measures.

8. Set-up of a conservation advisory group to provide technical assistance to the Bolivian industry in the implementation of energy conservation and conversion projects. Training in energy management techniques.

9. Evaluation of LPG reserves and investment requirements for extracting, transporting and distributing LPG.

10. Pre-feasibility study for the use of compressed natural gas (CNG).

Empresa Nacional de Electricidad

11. Preparation of a cost manual to uniform cost estimates of power projects and enable valid comparison among alternatives.

12. Study of the national electric tariff level and structure.

13. Organizational study of the electric sector.

14. Formulation of a national rural electrification plan.

Ministry of Agriculture

15. Formulation of a reforestation program, including the following specific projects:

    (a) Intensive reforestation in ORURO for charcoal production.

    (b) Extension of the reforestation projects in the rural areas of the Altiplano, Chuquisaca and Tarija.

    (c) Applied research in agro-forestry.

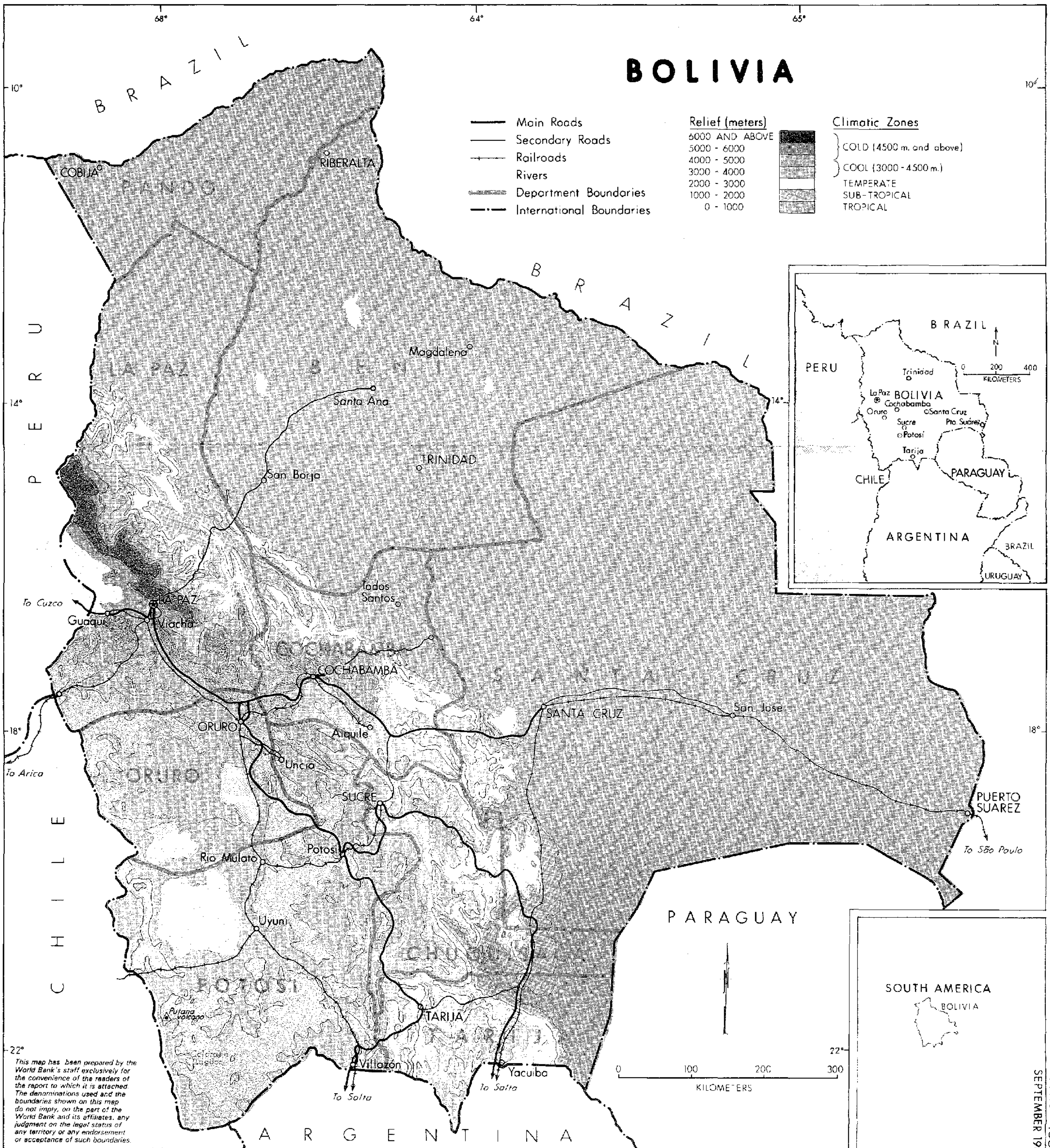
    (d) Training in forestry management and charcoal production.

Special Studies

16. Options increase benefits from international hydrocarbon trade.

17. Evaluation of energy efficiency in sugar plants. Economic analysis of the uses of surplus bagasse including alcohol production.

18. Pre-feasibility study on the use of mineral sulphur for road paving.



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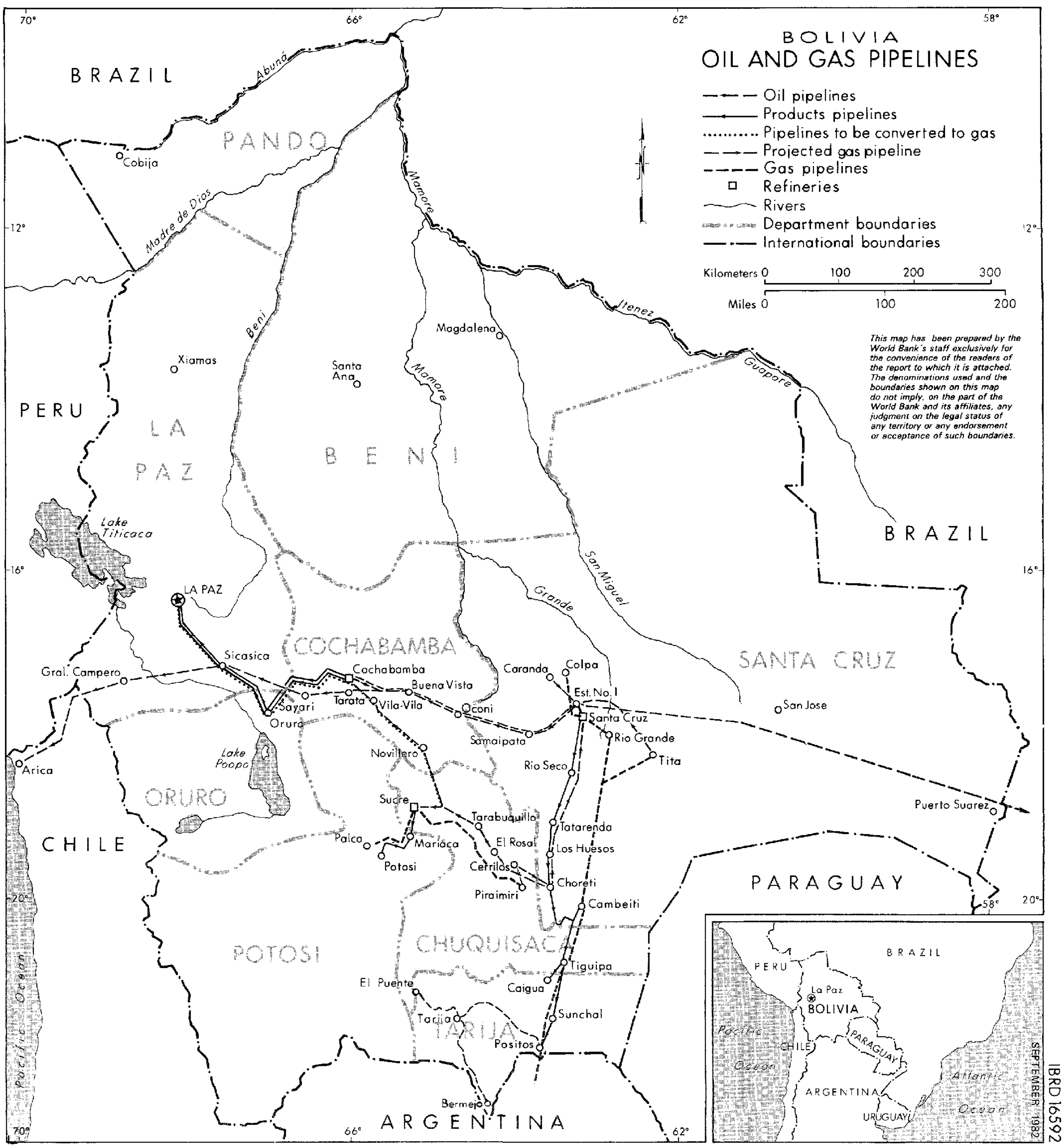
SEPTEMBER 1982


BOLIVIA
OIL AND GAS PIPELINES
Oil pipelines
Products pipelines
Pipelines to be converted to gas
Projected gas pipeline
Gas pipelines
Refineries
Rivers
Department boundaries
International boundaries
Kilometers 0 100 200 300
Miles 0 100 200
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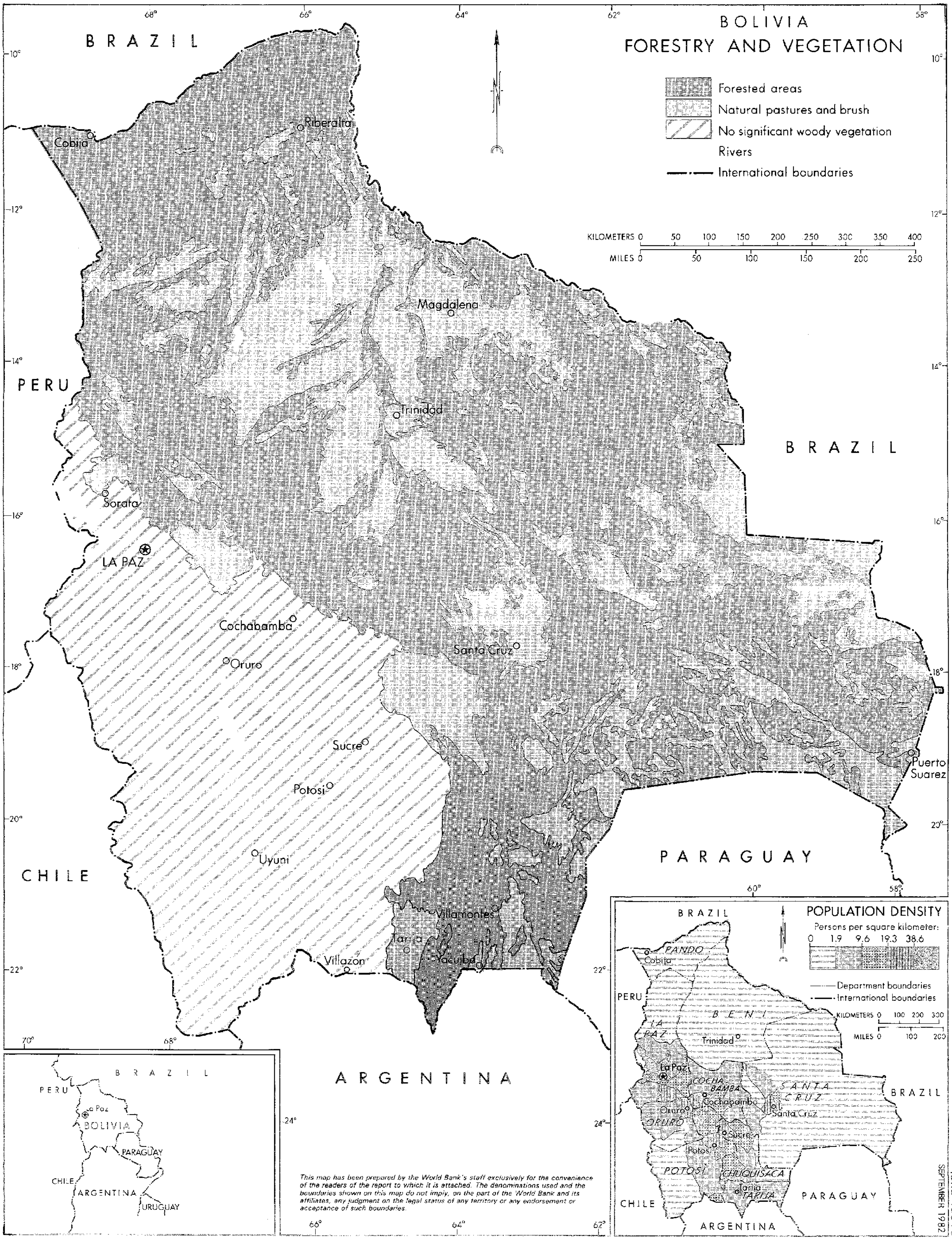
BRAZIL
PERU
CHILE
PARAGUAY
ARGENTINA
PANDO
LA PAZ
BENI
COCHABAMBA
SANTA CRUZ
ORURO
POTOSI
CHUQUISACA
TARIJA
Cobija
Xiamas
Santa Ana
Magdalena
LA PAZ
Sicasica
Gral. Campero
Arica
Sayari
Oruro
Cochabamba
Tarata
Vila-Vila
Buena Vista
Oconi
Samaipata
Caranda
Colpa
Est. No. I
Santa Cruz
Rio Grande
Tita
San Jose
Puerto Suarez
Novillero
Rio Seco
Sucre
Palca
Mariaca
Potosi
Tarabuquillo
El Rosal
Cerrillos
Piraimiri
Tatarenda
Los Huesos
Choreti
Cambeiti
Tiguipa
Caigua
El Puente
Tarija
Sunchal
Positos
Bermejo
Lake Titicaca
Lake Poopo
Pacific Ocean
Abuná
Madre de Dios
Beni
Mamore
Itenez
Guapore
San Miguel
Grande
70°
66°
62°
58°
12°
16°
20°
BRAZIL
PERU
La Paz
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
Pacific Ocean
Atlantic Ocean
SEPTEMBER 1982
IBRD 16592


BOLIVIA
FORESTRY AND VEGETATION
Forested areas
Natural pastures and brush
No significant woody vegetation
Rivers
International boundaries
KILOMETERS 0 50 100 150 200 250 300 350 400
MILES 0 50 100 150 200 250
BRAZIL
PERU
CHILE
ARGENTINA
PARAGUAY
Cobija
Riberalta
Magdalena
Trinidad
Sorata
LA PAZ
Cochabamba
Oruro
Santa Cruz
Sucre
Potosi
Uyuni
Villazon
Tarija
Villamontes
Yacuiba
Puerto Suarez
BOLIVIA
URUGUAY
POPULATION DENSITY
Persons per square kilometer:
0 1.9 9.6 19.3 38.6
Department boundaries
International boundaries
KILOMETERS 0 100 200 300
MILES 0 100 200
PANDO
BENI
LA PAZ
COCHABAMBA
SANTA CRUZ
ORURO
POTOSI
CHUQUISACA
TARIJA
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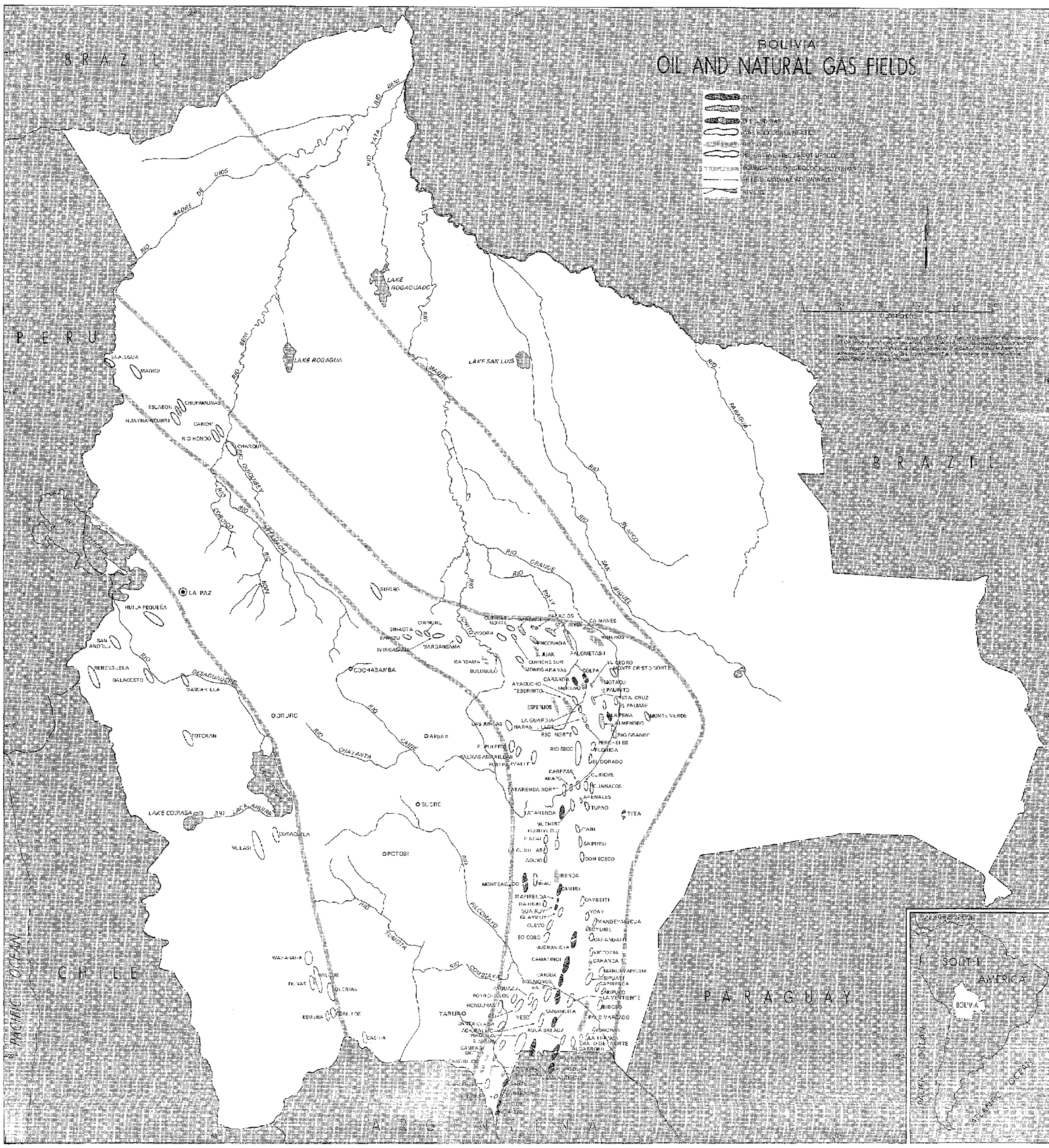
SEPTEMBER 1982



BOLIVIA
OIL AND NATURAL GAS FIELDS
BRAZIL
PERU
CHILE
PARAGUAY
PACIFIC OCEAN
LA PAZ
COCHABAMBA
ORURO
SUCRE
POTOSI
LAKE ROGAGUA
LAKE SAN LUIS
LAKE COIPASA
TARIJA
SANTA CRUZ
SOUTH AMERICA
BOLIVIA