Report No. 5865-EC

Ecuador: Issues and Options in the Energy Sector

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Report of the Joint UNDP/World Bank Energy Sector Assessement Program

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Report No. 5865-EC

ECUADOR

ISSUES AND OPTIONS IN THE ENERGY SECTOR

DECEMBER 1985

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ABSTRACT

The main energy issues in Ecuador concern petroleum exploration, development of existing oil fields, the role of the State Petroleum Corporation (CEPE), inadequate energy pricing, and the power subsector's financial difficulties.

Petroleum exploration is the key investment priority in Ecuador's energy sector. The country is so dependent on oil that whatever happens to the volume of oil production or to oil prices, overshadows developments in the rest of the economy. Nevertheless, past exploration efforts in Ecuador have been insufficient, resulting in a steady decline in petroleum reserves of almost 30% between 1973 and 1984.

In accordance with the country's requirements and good prospects for future oil discoveries, the overall strategy for the petroleum subsector should aim to increase current petroleum production as long as production is backed by a strong exploration program. No other investment in Ecuador has a higher expected rate of return, a quicker pay-off, and a more dramatic impact on exports.

The role of CEPE should be redefined and the government should take actions to implement its decision. CEPE is not able to function as an efficient oil company mainly because of limited exploration involvement, and insufficient autonomy permitted by the petroleum legislation.

Petroleum pricing policy involves heavy subsidies with retail prices roughly 50% of economic cost, and power tariffs exceedingly low when compared to marginal cost.

The power subsector has been facing serious financial difficulties for a number of years. These only became apparent at the turn of the decade after the sector had started an ambitious investment program to be financed mostly by oil revenues.

ACRONYMS

BEDE	Banco Ecuatoriano de Desarollo	(Development Bank of Ecuador)
BNF	Banco Nacional de Fomento	(National Development Bank)
CAF	Corporacion Andina de Fomento	(Andean Development Fund)
CEDEGE	Comision de Estudios para el Desarrollo de Rio Guayas	(Guayas Basin Development Commission)
CEPE	Corporacion Estatal Petrolera Ecuatoriana	(Ecuadorian Petroleum State Corporation)
CONADE	Consejo Nacional de Desarollo	(National Development Office)
DNH	Direccion Nacional de Hidrocarburos	(Hidrocarbons National Directorate)
EEC	Comunidad Economica Europea	European Economic Community
EMELEC	Empresa Electrica del Ecuador	(Ecuadorian Electric Company)
FONAFOR	Fondo Nacional Forestal	(National Forestry Fund)
GOE	Gobierno de la Republica del Ecuador	(Government of Ecuador)
INE	Instituto Nacional de Energia	(National Energy Institute)
INECEL	Instituto Ecuatoriano de Electrificacion	(Ecuadorian Electrificiation Institute)
MAG	Ministerio de Agricultura	(Ministry of Agriculture)
MOF	Ministerio de Finanzas	(Ministry of Finance)
MRNE	Ministerio de Recursos Naturales y Energeticos	(Ministry of Natural and Energy Resources)
OLADE	Organication Latinoamericana de Energia	(Latin American Energy Organization)
OPEC	Organization of Petroleum Exporting Countries	
PRONAF	Programa Nacional Forestal	(National Forestry Program)
USAID		U.S. Agency for International Development

ABBREVIATIONS

B	Billion = 10^9	km	Kilometer
bbl	Barrel	kW	Kilowatt
bd	Barrel per day	kWh	Kilowatt hour
BTU	British thermal unit	LPG	Liquefied Petroleum Gas
CFD	Cubic feet per day	m^3	Cubic meter
GW	Gigawatt	MM	Million
GWh	Gigawatt hour	MT	Metric Ton
ha	hectare	MW	Megawatt
kcal	Kilocalorie	MWh	Megawatt hour
kgoe	Kilograms of oil equivalent	toe	Tons of oil equivalent
ktoe	Kilo tons of oil equivalent	TPD	Ton per day

CURRENCY EQUIVALENTS (1984)

Official exchange rate applied to selected imports:
US$1 = 65 sucres

Average effective exchange rate:
1 US$ = 96.95 sucres
which has been used throughout the report.

ENERGY CONVERSION FACTORS

Petroleum	
Crude Oil	139 toe = 1,000 bbl
LPG	114 toe = 1,100 bbl
Gasoline	122 toe = 1,000 bbl
Kerosene & Jet Fuel	133 toe = 1,000 bbl
Diesel	139 toe = 1,000 bbl
Fuel Oil	153 toe = 1,000 bbl
Biomass	
Fuelwood	300 toe = 1,000 ton
Charcoal	650 toe = 1,000 ton
Bagasse	209 toe = 1,000 ton
Electricity	86 toe/GWh

This report is based on the findings of an energy assessment mission which visited Ecuador in January 1985. The full-time members were Bernard Zinman (Mission Leader); Gabriel Sanchez-Sierra (Deputy Mission Leader); Ignacio Rodriguez (Mineral Economist); Fernando Lecaros (Power Economist); William Simmons (Petroleum Engineer); Jean Pierre Angelier (Energy Planner); John Shillingford (Refinery Specialist); and Sergio Trindade (Energy Conservation Specialist). The following consultants participated on a part time basis: Peter Symborski (Gas Specialist) and Robert Chronowski (Forestry Specialist). All concerned with preparing the report, especially the principal authors, Gabriel Sanchez-Sierra and Ignacio Rodriguez, would like to express their gratitude to (the late) Bernard Zinman for his wise guidance and wholehearted support.

TABLE OF CONTENTS

TABLES

ANNEXES

MAPS

SUMMARY AND RECOMMENDATIONS

1. Ecuador has abundant energy resources which, if exploited properly, could improve the country's development prospects during the 1980s. Its major resources consist of: 1.5 billion bbl of petroleum 1/ (928 MMbbl proven and 526 MMbbl probable), 550 BCF of natural gas, 21,000 MW of hydropower, and abundant forest resources. Despite substantial potential energy resources, Ecuador's per capita consumption of energy (533 kgoe) is low compared with the Latin American average.

2. Ecuador's growth prospects will depend critically upon petroleum exports and international petroleum prices. The discovery and exploitation of oil in Ecuador initiated an unprecedented economic boom in the 1970s. Since then, petroleum has been the backbone of the Ecuadorian economy. In 1984, petroleum accounted for about 72% of all commodity exports, 15% of the country's GDP, 50% of Central Government revenues, and 74% of the total final domestic energy demand.

3. The major issues in Ecuador revolve around investment priorities, energy demand management and institutional problems. Although the country has a plentiful supply of energy resources, it has limited financial resources which must be allocated efficiently according to priorities. In energy demand management, the present pricing policy is a major constraint to an efficient allocation of energy resources. Lack of conservation incentives, contraband trafficking of petroleum products to neighboring countries, illegal interfuel substitution, and revenue losses are all a consequence of this policy. With respect to institutional problems, procurement bottlenecks and the undefined role of major institutions in the energy sector are the main concerns.

Investment Priorities

4. Short term economic conditions in Ecuador will require a setting of priorities in public investment in the 1985-1988 period. Taking into account the public investment review requested by the Government of Ecuador (GOE) and conducted by the World Bank in early 1985, the mission reviewed the energy sector's investment program with the purpose of seeking an overall reduction of one-third.

Petroleum

5. Petroleum exploration is the key investment priority in Ecuador's energy sector. The country is so dependent on oil that

1/ DNH has estimated total reserves at a more conservative 1.13 billion bbl.

whatever happens to the volume of oil production or to oil prices overshadows developments in the rest of the economy. Nevertheless, past exploration efforts in Ecuador have been insufficient, resulting in a steady decline in petroleum reserves of almost 30% between 1973 and 1984. After 1988, production rates from existing fields will not be able to maintain crude oil exports at the 1982 levels and provide for the growing demand on the internal market. New possibilities exist, however, as a result of the Ecuadorian Congress approving new legislation to revise the Hydrocarbon Law in August 1982 in order to attract private investors. This legislation has been successful, as evidenced by the recent signing of exploration service contracts with Occidental Petroleum Company in January 1985, Belco in June 1985, and anticipated contracts with Exxon and possibly other companies.

6. The mission agrees with the Government's overall strategy of attracting private capital for future oil exploration but is concerned about the limits placed on the scope of the State Petroleum Corporation (CEPE) activities. CEPE should continue in low risk exploratory work in view of the Corporation's good discovery rate (62.5% from 1975 thru 1984) and the long lead-time required before production from any new field can take place, since production resulting from private investment in exploration may not start until the 1990s. In order that new discoveries can quickly be developed for exploitation and to reduce the risk level, CEPE should concentrate on those prospects located close to their oil fields now producing in the Oriente. This would ensure an increase in petroleum supply over the next several years, and maintain an adequate reserves/production ratio in the near and medium-term. CEPE should also conduct more detailed seismic surveys, geochemical prospecting, and geological studies in relatively unknown but attractive areas to assist in the promotion of new service contracts in such areas by private companies (paras. 3.8-3.11 and 3.39-3.40).

7. Development of existing oil fields is the most profitable investment the GOE can undertake in the energy sector. Purchasing of artificial lift equipment will be crucial to increasing output in certain CEPE oil fields in the Oriente where US$40 million in capital expenditures have already been made in developing the fields involved. The CEPE-Texaco Consortium could increase its production by 20,000 bd, without doing harm to the oil fields, which would permit an increase in exports valued at about US$200 million annually. No other investment in Ecuador has a higher expected rate of return, a quicker pay-off, and a more dramatic impact on exports.

8. In accordance with the country's requirements and good prospects for future oil discoveries, the mission considers that the overall strategy for the petroleum subsector should aim to increase current petroleum production as long as production is backed by a strong exploration program. This would provide revenue which could be used for further exploration and to alleviate Ecuador's urgent need for foreign exchange. In view of the higher risk involved in the Santa Elena oil

fields, rehabilitation program and its lower priority, it should be carried out under a joint-venture operation (paras. 3.12-3.17 and 3.41-3.44).

9. Ecuador's refinery strategy is justified in expanding refining capacity to balance local production with demand. This appears to be a prudent decision since the future of the refineries in the Caribbean that supply Ecuador is at this time unknown, and the petroleum market is very unstable. Ecuador does not plan to emulate the larger OPEC nations, in attempting to refine on a large scale for the export of products.

10. The expansion of the Esmeraldas refinery (US$125 million) is attractive, as the refinery has a yield structure well suited to domestic demand. The mission estimated an IRR of 15% over a 15-year life. Expansion of the refinery will be commissioned in 1988 and is expected to increase its refining capacity by 34,000 bd to 90,000 bd. The planned Amazonas refinery (US$23 million) has a very good return on investment (35-47%) due to savings in pipeline transportation costs from Oriente-Esmeraldas-Quito and road transportation costs. It will be located in the Oriente region with a capacity of 10,000 bd. The mission agrees with the present informal position of the GOE to postpone indefinitely the proposed Atahualpa refinery (75,000 bd) because of its high investment cost and negative rate of return (paras. 3.45-3.47).

Natural Gas

11. From a preliminary analysis, the mission does not consider natural gas an investment priority for the short run. Although the gas from the Gulf of Guayaquil has a potential market, there are many uncertainties which must be resolved first regarding the size of reserves, geology, market and legal exploitation rights. Utilization of natural gas for power generation in the Guayaquil area is the most attractive option in terms of gas utilization, but its economic merit depends on the generation policy of the Ecuadorian Electrification Institute (INECEL). Since hydropower will be available, the expansion of INECEL's transmission system in the next five years will reduce the need for gas in the power sector. The mission recommends that reliable gas reserve estimates be established, a comprehensive gas utilization study be carried out before any large investment is undertaken in the area and the legal uncertainties about exploitation rights be clarified. (paras. 4.8-4.20).

12. Historically, the associated natural gas in the Oriente has been flared, with only nominal volumes utilized as fuel and for gas lift operations. Much of the gas has been flared as a result of: low gas/oil ratios, remote production areas, low concentration of population and large distances to consumption centers, and lack of infrastructure. CEPE's current program is now oriented to improve gas utilization and maximize the recovery of condensates. In a preliminary analysis the mission has found that the gas used to replace diesel and centrifuged crude oil in petroleum operations is economically attractive and well

justified to be implemented. Although power generation and recovery of condensates may be economically attractive, they must be analyzed in detail because of the scattered power demand potential and constraints mentioned above (paras. 4.21-4.31).

Electric Power

13. Investment priorities recommended by the mission include the following: (a) to finalize the construction of the Agoyan hydroelectric project; (b) to maintain INECEL's transmission expansion program; (c) to continue with INECEL's distribution expansion program; and (d) to continue with the preparation of various feasibility studies.

14. The Agoyan project (156 MW), which is scheduled to be finished in 1987, will assure enough generating capacity to satisfy demand until 1993. The mission concludes that since the project is well advanced, finishing the project according to its present schedule is completely justified (para. 5.35).

15. Expansion of the Transmission System. INECEL's transmission expansion program can be considered reasonable and should be maintained, although some deferral is possible in view of the recommended postponement of some of the hydrogeneration investments (Paute C and Daule Peripa - see para. 18 below). The system's expansion will improve reliabiltiy, reduce losses and make energy available for further electrification (paras. 5.38-5.39).

16. Distribution and Rural Electrification. The mission considers that the amount of investment allocated for distribution and rural electrification is well justified. In view of Ecuador's low electrification rate (61%), there is a need to stimulate the demand for electricity, as a way of promoting economic growth (para. 5.40).

17. Feasibility studies. The mission considers that the amount budgeted for studies is adequate. Studies included in INECEL's investment plan will provide the basis for planning and will be used in the revision of the master plan. In particular, feasibility studies for projects such as Cardenillo and Sopladora are crucial for the definition of the Paute River complex which is the backbone of hydropower development in Ecuador. Furthermore if studies are to be ranked in order of priority, the mission suggests that emphasis be placed on "small" projects (100-300 MW) that allow greater planning flexibility than the larger and riskier plants that ultimately can be more expensive for a country facing serious macroeconomic and financial constraints (para. 5.41).

18. The Paute C (500 MW) and Daule-Peripa (130 MW) projects which are included in INECEL's investment program should be postponed. 2/ Given the complexity of the sedimentation problem in developing the Paute River, it would be advisable to postpone civil works on the Paute C project until more information about sediments, including proposals for handling them, becomes available. Even if Paute C is not initiated before 1986 or 1987, it would still be finished before 1994, which is the earliest date it might be needed. In view of the present resource constraint and the fact that installed capacity would suffice to meet peak demand in 1993, it would be advisable to defer construction of the Daule-Peripa hydropower component two years and start construction in 1989 (paras. 5.36-5.37).

Fuelwood

19. From a preliminary analysis, the mission does not consider investments in reforestation for energy purposes to be a priority for the short term. It has been found that the opportunity cost of fuelwood (when energy efficiency is taken into account) is more than twice that of kerosene. This is due to high reforestation costs in Ecuador associated with poor terrain and harsh climate in the deforested areas such as in the southern Sierra. The mission considers that before any major reforestation program for energy purposes is undertaken, a detailed benefit/cost analysis both of a reforestation program and kerosene utilization program should be carried out (para. 6.15).

Energy Demand Management

Energy Pricing

20. Energy pricing in Ecuador has been a highly sensitive, political issue, with past increases leading to riots and strikes. Effective energy conservation and appropriate fuel choices will be difficult to implement until prices reflect their actual costs of supply.

21. Petroleum pricing policy involves heavy subsidies (retail prices are roughly 50% of opportunity cost); the total subsidy in 1984 was over US$600 million, comprising an implicit (economic) subsidy of US$515 million and an explicit (financial) subsidy of US$93 million consisting of losses incurred by CEPE. In addition, low domestic prices for petroleum products have encouraged illegal interfuel substitution in the industrial and transport sectors, and large-scale smuggling of these products to Colombia and Peru resulting in financial losses estimated at US$57 million in 1984. the Ecuadorian Energy Institute (INE) estimates

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2/ The GCE has already started the civil-works in Paute C and the irrigation stage of Daule-Peripa which is a multi-purpose project.

that the volume of these illegal petroleum product exports represents two-thirds of those imported by Ecuador and about 10% of Ecuador's total consumption. The Ecuadorian Government should adopt the concept of opportunity cost as the pricing principle for all petroleum products except kerosene, and prices should be pegged to the dollar and increased gradually at a rate higher than internal inflation. The GOE may consider maintaining the subsidy on kerosene for low-income households since kerosene remains the most economic cooking-fuel option for Ecuador, taking into account a system which would avoid fraudulent use (paras. 2.3-2.7).

22. Taking into consideration the price-ceilings provided in the Hydrocarbon Law which cover only the costs of production and distribution, in the absence of changing the law, the mission recommends some parallel actions such as: (a) analyzing the implementation of a subsidized public transport system while still being able to raise the price of gasoline to its opportunity cost; and (b) reducing fraudulent blending of products.

23. Electricity Tariffs. INECEL's tariffs are exceedingly low when compared to marginal cost. The mission has estimated that the marginal costs vary from US¢5.7 to U¢9.7/kWh, depending on voltage level; this compares to an average tariff level of US¢3.4/kWh. Taking into account the political constraints that prevent substantial readjustment of electricity tariffs, the mission considers that power tariffs should be adjusted gradually towards their long-run marginal cost level, by periodic increases at a rate higher than internal inflation (paras. 2.8-2.11). 3/

Energy Conservation

24. An efficient allocation of resources will be realized in Ecuador only when prices are increased to reflect their opportunity costs. Until then, the mission has identified various possibilities in the household, transport and industrial sectors. In the household sector, a benefit/cost analysis of reforestation versus kerosene utilization should be carried out. Although Ecuador's industry is predominantly light and small, substantial energy savings could be achieved by improving efficiency in refineries and in cement plants, reducing fuel oil and diesel oil consumption in sugar mills by using surplus bagasse more efficiently, and replacing the diesel oil used in power generation with available hydropower. The transport sector, which is the single most important user of energy in Ecuador (50% of commercial energy), can achieve energy conservation in two ways: (a) interfuel substitution; and (b) increasing transport system efficiency. Maintenance of equipment and incentives to improve freight transport by increasing back-hauls, would introduce energy efficiency standards (paras. 2.13-2.40).

3/ Presently (Dec/85), tariffs are being increased by 3% per month, exceeding the inflation rate.

Institutional Issues

25. Overall coordination of the energy sector by the Ministry of Natural and Energy Resources (MRNE) is sound. However, much improvement is required in the major institutions in the energy sector for efficient functioning.

26. The major issue for the petroleum subsector concerns redefining the role of CEPE. CEPE is operating under deep-seated legal rigidities and bureaucratic delays. In addition, the Hydrocarbons National Directorate (DNH) is duplicating some activities carried out by CEPE. CEPE's autonomy should be ensured and solutions to procurement bottlenecks should be provided. A very clear distinction should be made between executing national hydrocarbon policies under DNH, and the actual operations by CEPE and private companies within the Government's petroleum policies.

27. CEPE's ability to operate as an oil company is seriously impeded by its lack of financial autonomy. CEPE should have enough resources to finance a sound investment program developed jointly with DNH. The mission concluded that a detailed financial analysis of CEPE and an analysis on the distribution of oil revenues within the country's macroeconomic context should be carried out. The mission recommends that a financial strategy for CEPE should be defined, including investment and resource requirements linked to an overall policy in the medium and long-term. (paras. 3.27-3.36)

28. The power subsector has been facing serious financial difficulties for a number of years. These only became apparent at the turn of the decade, after the subsector had started on an ambitious investment program designed to replace thermal with hydroelectric generation and to interconnect the country's isolated regional systems to a national power grid. The investment program was to be financed mostly by oil revenues at a time when Ecuador was enjoying unprecendented prosperity arising from the increase in oil prices and its incipient role as an oil exporting country. The power subsector should define a financial strategy that will increase net internal cash generation, reduce its dependence on oil revenues and external borrowings.

29. INECEL suffers from two institutional problems, one internal to the company and the other external. The internal problems which obstruct efficient management of the company mainly concern the abundance of concessionaires, even after an effort to group the companies together. At present INECEL's management is seeking solutions to these problems through an institutional development program. The mission considers this of high priority for INECEL.

30. The external problems mainly concern legal requirements which create obstacles to the effective functioning of the company, especially with respect to imports, bidding, and contracts. Resolution of these

legal problems, especially as they relate to the Contraloria, would require substantial modification of the basic electricity law. Nevertheless, in the short term, groups could be formed to improve management operations in INECEL. In addition, the Manager of the Company should be authorized to purchase equipment for amounts in excess of the unrealistic limit of US$10,000 (paras. 5.27-5.32 and 5.42-5.45). 4/

31. Lack of coordination, plus insufficient funding and manpower, have prevented the National Forestry Program (PRONAF) from having an effective impact on the fuelwood subsector, especially in the area of reforestation. PRONAF should be reorganized in such a way that the needs of the forestry sector can be met in a cost effective manner and according to priorities. There are manpower constraints both in PRONAF headquarters and in district offices; the situation is aggravated by the inefficient institutional organization of PRONAF (para. 6.11).

32. INE, as the national energy planning center, appears to have placed much emphasis on areas with low pay-off on a national scale. This can be attributed to political sensitivities surrounding the main energy issues in petroleum and electric power. A redefinition of its role and reorganization is required. Greater emphasis is needed on priorities, intrasector analysis, demand management -- particularly energy pricing -- and economic feasibility work for specific projects (paras. 7.29-7.33).

Technical Cooperation Requirements

33. The ' sessment mission recommends the following as priority areas in which ·ollow-up technical cooperation studies would be useful in resolving some of the problems in the energy sector in Ecuador.

Subsector	Priority Areas Requiring Technical Cooperation
Petroleum	- Petroleum product pricing analysis (paras. 2.3-2.7).
	- Prefeasibility study on the implementation of a subsidized transport system which would permit public transport fares to remain at a low level while raising the price of gasoline to its economic cost (para. 2.7).
	- Prefeasibility study on increasing petroleum production in existing fields (paras. 3.15-3.17).

4/ This limit has been recently extended to US$100,000.

- Design and implementation of an integrated planning system for CEPE, including refineries, pipelines and terminals as an aid to investment planning (paras. 3.48-3.49).
- Identification of new areas for future petroleum exploration activities (para. 3.9).
- Analysis of CEPE's legal and organizational framework (paras. 3.27-3.33).
- Analysis of CEPE's financial situation and the distribution of oil revenues within the country's macroeconomic context (paras. 3.34-3.36).

Natural Gas

- Prefeasibility study on the market potential for the natural gas from the Gulf of Guayaquil (para. 4.9).

Electric Power

- Marginal cost and tariff analysis (paras. 2.8-2.12).
- Institutional development of INECEL and its subsidiaries (paras. 5.39-5.42).
- Technical services in updating and revising the existing generation and transmission models in INECEL's planning unit (para. 5.20).
- Operation of the Interconnected System (paras. 5.25-5.26).
- Loss reduction study (para. 5.26).
- Prefeasibility study on rural electrification - second phase (para. 5.40).

Fuelwood

- Prefeasibility study on comparison of reforestation for energy purposes and kerosene utilization (para. 6.15).

Geothermal

- Reevaluation of the Valle de los Chillos geothermal project for industrial use (paras. 7.7-7.8).

I. ENERGY IN THE ECONOMY

Country Background

1.1 Ecuador has a land area of 284,000 km^2 and is divided into three distinct geographic zones (IBRD Map No. 18179). The western coastal lowlands, which extend from the Pacific Ocean to the Andes, embrace one-fourth of the country's total area and have about one-half of the country's population. Guayaquil, on the Pacific coast, is Ecuador's largest city and the country's most important port. The high Andean Mountains, which run essentially north-south through the center of the country -- and have slightly under one-half of its population -- house the capital of Ecuador, Quito. The third geographic zone is the low-lying eastern, or Oriente region, which is jungle covered and drained by tributaries of the Amazon River and contains nearly all of Ecuador's proven oil reserves. The Oriente constitutes about one-half of the country's total area, but has less than 3% of the country's population. Ecuador's 1983 population was estimated at 8.2 million (45% urban) with a 2.5% rate of growth in the period 1974-1982.

Economic Situation

1.2 Ecuador entered the 1970s as one of Latin America's poorest countries, but an unprecedented boom in the economy began in 1972, spurred by large oil exports. The discovery and exploitation of petroleum in the Oriente initiated this boom in 1972. Ecuador became a member of OPEC in 1973. From 1972 to 1978, real GDP growth averaged about 9% annually. However, the country became overwhelmingly dependent on oil revenues and foreign borrowings. Between 1979 and 1981, GDP growth slowed to 5% p.a. because of the influence of the world economy, domestic political uncertainty, stagnating export earnings, particularly for oil, and lower rates of domestic investment. In 1982, GDP growth fell to 1.4%, and declined by approximately 3.5% in 1983. In 1984, real GDP grew by about 3.4% owing to the recovery of the agricultural sector from the floods that ravaged the countryside in 1982-83. Per capita GDP in 1984 was US$1,170.

1.3 Several problems that had been masked by high oil prices came to the fore in 1983, as the shaky foundation of Ecuador's seemingly strong balance of payments position became evident. Although the country's commodity exports increased from US$585 million in 1973 to US$2,365 million in 1983, this was a reflection of rising world oil prices rather than an increase in the absolute volume of exports. Petroleum exports actually declined between 1973 and 1983 -- from about 71.85 MMbbl to about 49.83 MMbbl. Petroleum imports, on the other hand, increased from about 0.189 MMbbl in 1973 to 6.84 MMbbl in 1983. The oil bonanza, however, allowed Ecuador to borrow abroad to finance its current account deficit with ease. As imports continued to outpace exports, the Government attempted to continue financing its current account deficit with medium and long-term borrowing from external sources, but commercial bankers were becoming increasingly reluctant to lend to Ecuador. The ensuing shortage of foreign exchange constrained output in industry and construction. In 1983, petroleum accounted for about 74% of all commodity exports (up from 0.4% in 1970), 14% of the country's GDP, and 50% of Central Government revenues. Table 1.1 shows the importance of petroleum in the Ecuadorian economy.

Table 1.1: RELATIVE IMPORTANCE OF PETROLEUM IN ECUADOR

	1970	1975	1980	1983
Petroleum exports as a percentage of total exports	0.4	61	62	74
Petroleum exports as a percentage of total imports	0.4	61	71	124
Petroleum as a percentage of GDP	1	11	12	14

Source: Mission estimates.

1.4 Ecuador's current account deficit situation deteriorated from US$377 million in 1977 to US$1,070 million in 1982 (8% of GDP) but, with the country's inability to borrow as much, improved to US$590 million in 1983. The total external debt had grown from US$1,264 million in 1977 to US$7,743 million in 1983. However, as a result of the recent rescheduling of the debt, the debt service ratio was brought down from 68% of exports to roughtly 30% over the next five years. Due to massive import reductions, the country's trade balance of goods improved dramatically from US$153 million in 1982 to US$670 million in 1983.

1.5 Ecuador is now emerging from the recession. It has both the human and natural resources to emerge quickly from the recession and to enter a period of sustained economic growth. The present Administration's policy in the energy sector reflects its overall approach toward economic development for the country -- namely, less of a role for public entities in revenue-producing industries, particularly petroleum, and a greater role for the private sector; reform of state-owned enterprises aimed at making them more efficient; and fewer government controls. Growth prospects will depend critically upon petroleum exports and international petroleum prices. The country is so dependent on oil that whatever happens to the volume of oil production, or to oil prices, overshadows developments in the rest of the economy. The devaluations of the sucre and the recent unification of the exchange rate are expected to bring about a major shift in relative prices, increasing the relative importance of petroleum in the economy.

Energy Resources

1.6 Ecuador is richly endowed with energy resources. Its longest known resource is hydropower, (21,000 MW) of which less than 5% of the total potential has been developed. Hydrocarbon resources are represented by about 1.5 billion barrels of oil (928 million proven and 586 million probable) and about 550 BCF of natural gas (360 BCF non-associated gas in the Gulf of Guayaquil and 190 BCF associated gas in the Oriente). Ecuador also has abundant forest resources in the thinly populated selva region.

Energy Balance, 1984

1.7 Petroleum is the main element in the Ecuadorian energy balance. In 1984, the domestic production of primary energy amounted to 14.8 million toe, of which 91% was crude oil, 7% biomass and 2% hydropower. Two thirds of the petroleum production was exported in the form of crude oil. Although the country's refineries processed 4.5 million toe of crude oil, the country had to import gasoline, diesel oil and LPG (a total of 0.5 million toe), as a consequence of the imbalance between the refinery's production and domestic demand. At the same time, Ecuador exported 1.1 million toe of fuel oil. Concerning final consumption; petroleum products met around 74% of the total final energy demand, while biomass accounted for 19% and electricity 7%. Table 1.2 shows a summary of the estimated 1984 energy balance and a breakdown of the balance is presented in Annex No. 1.

Table 1.2: SUMMARY ENERGY BALANCE, 1984
(Thousand toe)

	Biomass	Oil	Electricity	Total
Domestic Supply	1002	13475	363	14840
Exports a/	-	(10057)		(10057)
Imports	-	512	-	512
Demand	1002	3930	363	5295

a/ It includes crude oil and petroleum products.

Sources: INE and mission estimates.

International Comparisons

1.8 Ecuador used lower amounts of energy per unit of output than other Andean countries of similar per capita income levels. This is essentially explained by Ecuador's low industrialization level. The country's commercial energy consumption had the greatest increase in the period 1970-1983 as a result of the petroleum boom initiated in 1972, the very low prices of commercial energies, and high GDP growth over the period. A comparison of economic growth and commercial energy consumption patterns for neighboring countries is shown in Table 1.3.

Table 1.3: ECONOMIC GROWTH AND COMMERCIAL ENERGY CONSUMPTION

Country	1983 GDP/capita	1983 Energy Intensity	1970-1983 Growth Rates Energy Consumption	1970-1983 Growth Rates GDP
	(1982 US$)	(TOE/US$ million GDP)	(%)	(%)
Ecuador	1,141	438	5.7	7.0
Colombia	1,034	544	3.9	4.5
Peru	960	509	1.3	1.9

Source: IDB Economic and Social progress in Latin America - 1984 and OLADE Energy Balances.

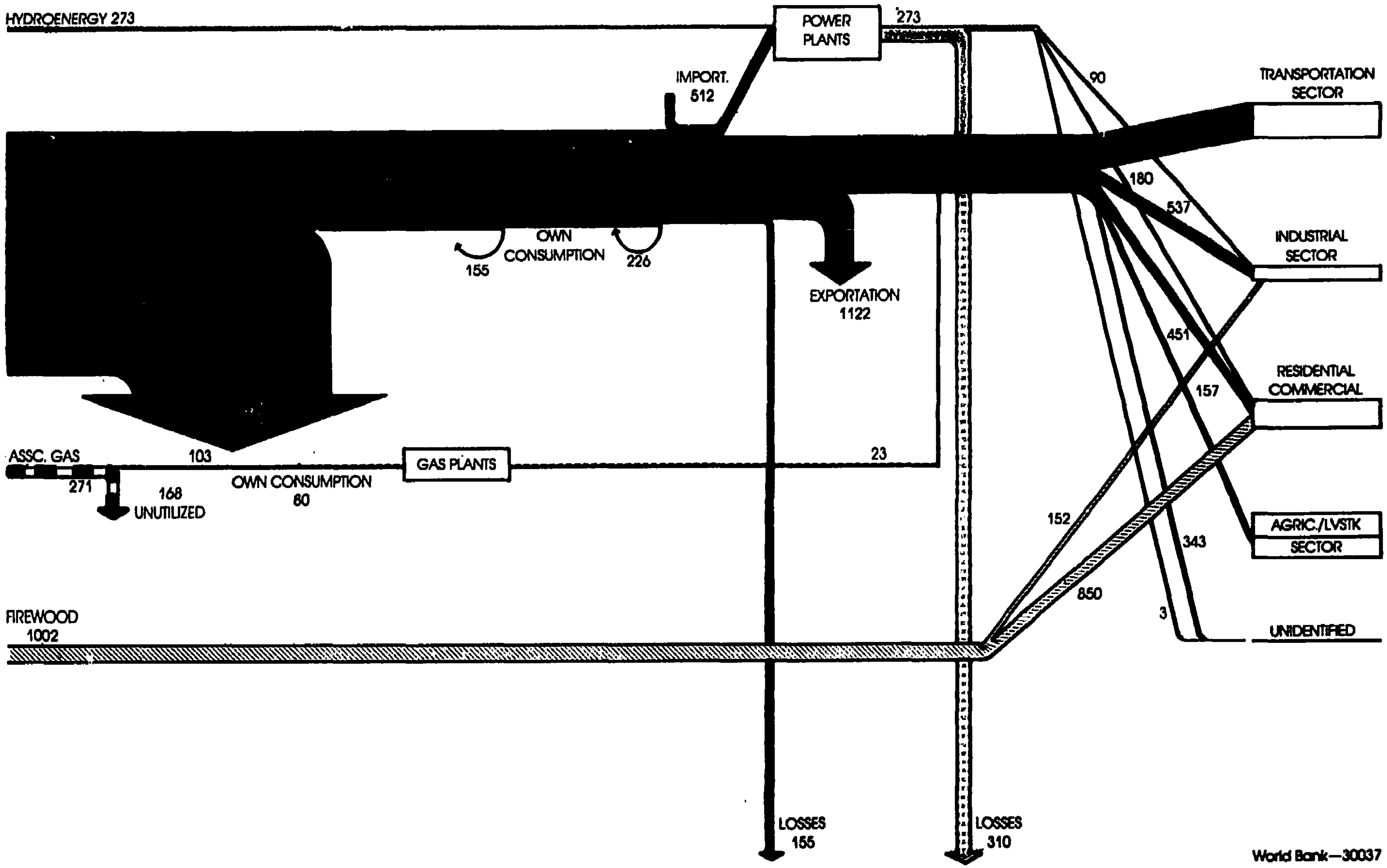
Energy Demand Projections

1.9 The problem with energy demand forecasts in Ecuador is that they are developed independently by agency and the working hypotheses are not necessarily the same. 5/ Although energy demand forecasts are made by INE, DNH, CEPE and INECEL, the last three institutions are only concerned with the type of energy they are in charge of. INE is the only organization which considers all the subsectors, but it still omits the energy sector's own energy consumption and excludes the smuggled petroleum product exports (see para. 2.6).

1.10 Since different models are utilized in the energy sector to develop demand projections, better coordination is needed between the institutions to avoid duplication and improve consistency. INE uses a simulation model called MEEDE-S while DNH, CEPE, and INECEL use econometric models based on linear regressions and extrapolations of past trends. To provide an analytical basis, and following the Bank's

5/ A commission was created in June 1985 to resolve the discrepancies.

1984 BASIC ENERGY FLOW ECUADOR
(TOE x 10^3)



World Bank—30037

macroeconomic outlook, the mission has considered a low and high case scenario for 1985 to 2000. The low-case scenario entails a GDP growth of 4% p.a. with a total energy demand growth of 4.9% p.a., while the high-case scenario considers 6% and 7.3%, respectively. Details about both scenarios are shown in Annex 2.

1.11 Significant increases in crude oil and petroleum product revenues in Ecuador are found to be highly dependent on petroleum product pricing policies. The mission has estimated that, under the low case scenario, a 50% real increase in petroleum prices in Ecuador would lead to a petroleum product consumption decrease of about 12% by 1990 and 17% by the year 2000 (compared with the scenario in which real prices are constant), allowing a higher surplus of crude oil and petroleum products for exports. Consequently, the total increase in revenue would be US$235 million in 1990 and US$612 million in 2000. Tables 1.4 and 1.5 show the impact of petroleum product price increases on final energy demand and total national oil revenues.

Table 1.4: FINAL ENERGY DEMAND
(thousand TOE)

	1990	1995	2000
Low Case a/			
Constant petroleum product prices	6695	8519	11963
50% increase in petroleum product prices	6081	7526	9419
High Case b/			
Constant petroleum product prices	7592	10844	15758
50% increase in petroleum product prices	6803	9334	13023

a/ 4% GDP growth, 4.9% total energy demand growth.
b/ 6% GDP growth, 7.3% total energy demand growth.

Source: Mission estimates.

1.12 Regarding electricity and fuelwood demand until the year 2000, two conclusions emerge: (a) Ecuador has sufficient energy resources to satisfy its electricity demand -- hydropower will continue to play an important role while other energy sources such as geothermal and natural gas can be developed; and (b) regional fuelwood supply deficits will continue and unless corrective actions are taken, growing deficits will aggrevate the deforestation situation, especially in the southern half of the central Sierra region. With respect to the latter, kerosene may offer an interesting economic alternative to fuelwood in the wood deficit areas (para. 6.7).

Table I.5: INCREASE IN NATIONAL OIL REVENUES RESULTING FROM A 50% INCREASE IN DOMESTIC PETROLEUM PRODUCT PRICES a/
(US$ million)

	1990	1995	2000
Low Case b/			
additional crude oil revenues	119	190	294
additional petroleum product revenues	116	205	318
Total	235	395	612
High Case c/			
additional crude oil revenues	151	288	579
additional petroleum product revenues	164	311	561
Total	315	599	1140

a/ Assuming a constant crude oil price of US$27 bbl thru the year 2000.
b/ 4% GDP growth, 4.9% total energy demand growth.
c/ 6% GDP growth, 7.3% total energy demand growth.
Source: Mission estimates.

II. ENERGY DEMAND MANAGEMENT

Energy Pricing

2.1 In a mixed economy such as Ecuador's, energy pricing is the most important policy instrument available to encourage energy conservation and appropriate fuel choices. The energy pricing policy in Ecuador which relies heavily on subsidies does not provide the right signal for efficient use of energy resources. This results in two negative effects in the country. The first refers to the absolute price level which determines the income of CEPE and INECEL and their capability to remain in business (paras. 3.34 - 3.36). 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 economic sources (paras. 2.13 - 2.40).

2.2 In the opportunity cost analysis, fuelwood used in the household sector is the most economic source of energy, as shown in Table 2.1. However, when the energy efficiency correction factor is taken into account, kerosene and low octane gasoline are the most economic while fuelwood is about twice as expensive as kerosene. Even if kerosene is subsidised it remains the best option to Ecuador in comparison with fuelwood produced by reforestation. In the transport sector, diesel oil is the most economic source of energy, followed by regular and premium gasoline. With respect to the industrial sector, fuel oil is the most economic source of energy, followed by diesel oil and kerosene, while electricity is two and a half times more expensive than fuel oil.

Petroleum Products

2.3 Domestic pricing of petroleum products is one of the most sensitive political questions in Ecuador. Past increases have led to riots and general strikes. Therefore, petroleum pricing policy in the past has involved heavy subsidies, with the prices of petroleum products in Ecuador being among the lowest in the world. From 1959 to early 1981 prices remaining unchanged (in absolute sucres). Since then, the Government has moved cautiously toward a more realistic pricing policy. The weighted average for all products has increased from 37% of international prices in 1983, to 40% in 1984, and to 50% in 1985 as a consequence of the latest price increase in December 1984. Table 2.2 shows the retail prices and opportunity costs of petroleum products as of January 1985.

Table 2.1: COMPARISON OF ENERGY PRICES IN ECUADOR, JANUARY 1985

	Opportunity Cost	Efficiency Correction Factor	Cost of Useful Energy	Relationship to Cheapest Fuel in the Sector
	(US$/toe)	(%)	(US$/toe)	
Household Sector				
Electricity	1,128	40	2,820	2.63
Fuelwood a/	117	5	2,340	2.18
Charcoal	302	15	2,013	1.88
LPG	291	25	1,164	1.09
Kerosene	269	25	1,076	1.00
Gasoline	268	25	1,072	1.00
Transport Sector				
Gasoline	268	20	1,340	1.29
Diesel Oil	260	25	1,040	1.00
Industrial Sector				
Electricity	663	80	829	2.48
Diesel Oil	260	50	520	1.56
Kerosene	269	50	538	1.61
Fuel Oil	167	50	334	1.00

a/ Based on investment of US$2.6 million/year with no return for 15 years, Plantation productivity 7.5 m^3/ha per year, 9,000 ha planted and 12% of capital cost.

Source: INE, CEPE and mission estimates.

Table 2.2: PETROLEUM PRODUCT RETAIL PRICES AND OPPORTUNITY COSTS JULY 1985

Fuel	Share of 1984 demand	Retail Prices	Opportunity Cost	Retail Prices
	(%)	($/gal)	($/gal)	as % of opportunity cost)
Gasoline a/				
Premium	1.3	0.67	0.83	81
Regular	31.7	0.52	0.83	63
Diesel Oil	22.5	0.41	0.85	48
Jet Fuel	3.4	0.26	1.32	20
Fuel Oil	24.9	0.26	0.47	55
Kerosene	7.9	0.14	0.84	17
LPG	6.3	0.22	0.66	33
Weighted Average	100.0	0.369	0.735	50.2

a/ The same opportunity cost is used because Ecuador imports only regular gasoline and obtains premium and low-octane by mixing in the country.

Source: CEPE; and mission estimates.

2.4 The legal basis for official price setting of petroleum products represents a major problem for the Government. The Hydrocarbon Law limits these prices to covering only the costs of production and distribution. These are obvious flaws in this arrangement in that no consideration is given to opportunity costs, nor does the law include depletion allowance as a cost component. Moreover, increasing product prices by taxing sales at the retail level is apparently not possible under the law (para. 3.29).

2.5 The mission has estimated that explicit and implicit subsidies in the domestic sale of petroleum products total more than US$600 million per year (23% of Ecuador's commodity exports and 5% of GDP). In 1984 the direct subsidy (losses occurred by CEPE), defined as the cost of imported products minus their retail prices, amounted to around US$93 million and the implicit subsidy, defined as the opportunity cost minus the retail price, amounted to almost US$515 million. Table 2.3 shows the estimated subsidies for 1984.

2.6 Low petroleum product prices in Ecuador also have allowed the development of illegal activities in the domestic market 6/ and large scale smuggling of these products in the direction of neighboring countries. In 1984, INE estimated that about 360,000 toe of petroleum products were illegal exports to Colombia and Peru. INE estimates that the volume of these illegal petroleum product exports represents two-thirds of those imported by Ecuador and about 10% of Ecuador's total consumption. Due to domestic subsidized product prices, the financial loss was estimated at US$57 million in 1985, or 61% of Ecuador's direct subsidy (see Annex 3).

Recommendations

2.7 To obtain a rational pricing policy in the petroleum subsector, the mission recommends that:

(a) The Ecuadorian Government adopt the concept of opportunity cost as the pricing principle for all petroleum products, with prices pegged to the dollar and increased gradually at a rate higher than internal inflation.

Taking into consideration the internal constraints (para. 2.3) that prevent the policy implementation mentioned in (a) above, some parallel actions are recommended by the mission.

6/ Mixing of low octane gasoline with regular gasoline in the transport sector and kerosene with diesel oil in the industrial sector.

Table 2.3: ESTIMATE OF PETROLEUM PRODUCT SUBSIDIES IN 1984

1. Direct Subsidy: (Cost of imported products less retail price).

	Cost of imports a/	Retail Price	Difference	Quantities Imported	Subsidy
	($/gal.)	($/gal.)	($/gal.)	(10^6 gal.)	(10^6 US$)
LPG	0.67	0.22	0.45	31.4	14.3
Reg. Gasoline	0.78	0.31	0.47	91.1	42.8
Diesel Oil	0.86	0.22	0.64	53.0	33.9
Total				175.5	93.4

2. Implicit Subsidy: (opportunity cost less retail price).

	Opportunity Cost a/	Retail Price	Difference	Volume of Sales b/	Subsidy
	($/gal.)	($/gal.)	($/gal.)	(10^6 Gal.)	(10^6 US$)
Gasoline					
Premium	0.78	0.41	0.37	12.2	4.5
Regular	0.78	0.31	0.47	296.9	139.5
Low-Octane	0.78	0.21	0.57	18.7	10.7
LPG	0.67	0.22	0.45	59.0	26.6
Kerosene	0.85	0.14	0.71	74.0	52.5
Jet Fuel	1.33	0.26	1.07	31.8	34.1
Diesel Oil	0.86	0.22	0.64	210.7	134.9
Fuel Oil	0.61	0.13	0.48	233.2	111.9
Total				936.5	514.7

a/ All costs except fuel oil are CIF Guayaquil plus inland storage and distribution costs.
b/ Excluding imports.

Source: MRNE; CEPE; and mission estimates.

(b) Since the strongest opposition to petroleum price increases is coming from the users of public transport, the GOE should study the implementation of a subsidized system which would permit it to maintain public transport fares at a low level while raising the price of gasoline to its opportunity cost.

(c) In order to avoid the fraudulent blending of kerosene with diesel oil and low octane gasoline with regular gasoline, a different coloring agent should be added to kerosene and the production of low-octane gasoline should be discontinued.

Residential users should utilize kerosene as the substitute for low-octane gasoline.

Electricity Tariffs

2.8 The level and structure of Ecuador's electricity tariffs do not reflect the real cost of this public service. The mission has estimated that marginal costs for the electric sector vary between US¢9.7/kWh and US¢5.7/kWh according to voltage level, compared to an average tariff of US¢3.4/kWh. Consumer tariffs are structured by blocks and each of the 16 INECEL subsidiaries has a different tariff level. The main difference is between the Sierra and the Coast. Except for kWh and kW charges for block deliveries and some industrial users, all tariffs are on a straight kWh basis with no allowance for peak/off-peak costs. Table 2.4 compares average bills in the Sierra with those in the Coast.

Table 2.4: COMPARISON OF AVERAGE BILLS IN THE SIERRA AND THE COAST

	Sierra (US¢/kWh)	Coast (US¢/kWh)
Residential Rates		
R-1 (60 kWh/month)	1.1	1.7
R-2 (200 kWh/month)	3.6	4.2
Commercial Rates		
C-1 (60 kWh/month)	1.8	2.1
C-2 (350 kWh/month)	4.0	4.2
C-3 (2000 hours/year)	4.7	4.7
Industrial Rates		
I-1 (10 kW)	3.2	3.8
I-2 (50 kW, 2000 hours/year)	3.7	4.0
I-3 (a - 2400 hours/year)	4.1	4.4
(b - 4800 hours/year)	3.5	3.8
(c - 5500 hours/year)	3.3	3.6

Source: INECEL.

2.9 INECEL's tariffs are exceedingly low when compared to marginal cost. As a first preliminary step to tariff analysis, marginal costs were estimated for INECEL's system. Reference tariffs based on marginal costs yield the values shown in Table 2.5. At high voltage levels, capacity charges are 20% of marginal costs, peak energy charges 25%, and off-peak energy charges 59%. At medium voltage levels, peak energy charges are half while off-peak energy charges are about equal to marginal costs. At low voltage levels energy charges are about 40% of marginal costs. Annex 4 shows the marginal cost and tariff analysis provided by the mission.

Table 2.5: ELECTRICITY REFERENCE TARIFFS BASED ON MARGINAL COSTS ANALYSIS

	Energy Peak	Energy Off-Peak	Capacity
	(US¢/kWh)		($/kW per year)
(a) Double meter consumers:			
HV block sales	6.4	2.7	119
MV loads	6.7	2.8	164
(b) Single meter consumers:			Energy US¢/kWh
Industry			5.7
Commercial off-peak users			5.5
Low Voltage users a/			9.7

a/ Mainly residential.

Source: INECEL and mission estimates.

2.10 It appears that the substantir' readjustments to tackle the present tariff distortions would be difficult to implement in the short term due to political constraints. Tariffs based on marginal cost analysis would provide a pricing signal that correctly reflects to the Ecuadorian economy the cost of developing additional hydro and transmission lines. However, such a measure can only be taken as part of a national energy strategy that would bring substitute fuel costs (fuel oil, diesel) in line with their opportunity costs; otherwise, there would be perverse incentives to continue using present thermal facilities at subsidized fuel prices instead of replacing them with INECEL's hydroplants.

2.11 A more feasible approach to implementing a tariff reform seems to be based on gradual increases. Present plans for tariff adjustments call for raises of 2% per month in nominal (sucre) terms. Due to certain categories that are excluded from this raise, the real rate of increase is about 1.8% per month (24% per year). If a target date (Jan. 1989) is set to reach marginal cost levels, rate increases in real terms would have to average around 2.6% per month for residential users and 1.5% for medium voltage supplies. Given that inflation is assumed to be at least 16% per year, the nominal monthly increases would have to be 3.9% and 2.4%, respectively. Tariff reforms should be seen as a concerted effort to seek efficiency within the energy sector as a whole. If consumer rates are readjusted without readjusting block sales tariffs, end-use consumption would presumably become more efficient but the extra income would only benefit INECEL's subsidiaries and wouldn't reach the generation level that requires most of the investment.

Recommendations

2.12 To obtain a rational pricing policy in the power subsector, the mission recommends that INECEL take the following actions:

(a) Adjust power rates gradually towards their long run marginal cost level, by means of periodic increases at a rate higher than internal inflation.

(b) Seek to unify consumer tariffs insofar as (i) utilities are interconnected with INECEL's main grid and (ii) cost differences between utilities at the subtransmission and distribution level are not significant.

(c) Introduce double metering for larger industrial and commercial users connected at MV levels, eliminating present block structures.

Energy Conservation and Substitution

The Structure of Energy Demand

2.13 In 1984, Ecuador consumed 4.5 million toe of energy. Per capita energy consumption was 533 kgoe, compared with a world average of 1,500 kgoe and an average for Latin America of 1,000 kgoe. Petroleum products met 72% of total demand, electricity 6%, and biomass 7/ the remaining 22% (see para. 1.6).

2.14 Commercial energy consumption amounted to 3.46 million toe in 1984, represented by: gasoline 35%, fuel oil 20%, diesel oil 18%, other petroleum products 19%, and electricity 8%. The transport sector is the most important consumer of commercial energy (50%), followed by industry (18%) and households (18%).

2.15 Biomass energy consumption in Ecuador totaled one million toe in 1984, represented by fuelwood 85% (including a minimal amount of charcoal), and bagasse 15%. Fuelwood accounted for 57% of the energy consumption in the household sector and bagasse supplied 20% of the energy consumption in the industrial sector.

The Household Sector

2.16 Energy Consumption. The household sector consumes about a third of all the energy used in Ecuador and its share remained roughly constant over the 1979-1984 period. The most important source of energy

---

7/ Fuelwood, bagasse and charcoal.

for the sector is fuelwood, which supplied 57% of the total in 1984, followed by petroleum products 30%, 8/ and electricity 13%. Kerosene is the second most important source of energy for the household sector in Ecuador, although its contribution is dropping, and that of LPG and electricity is increasing.

2.17 Urban Sector. The urban sector has to a great extent switched over to modern fuels; only an estimated 140,000 toe of fuelwood was consumed in 1984. This represents about 10% of the total household energy consumption while the urban population makes up about one-half of the total population. The best conservation initiative consists of raising prices for the modern fuels; however, the price increases should take into consideration the impact on fuelwood demand -- particularly on the diminishing tree resources surrounding urban areas.

2.18 Rural Sector. The rural sector relies primarily on fuelwood as the household energy source. Although it has been estimated by INE that 42% of all the rural households now have a stove capable of burning kerosene or low octane gasoline, free collection of wood and cultural biases have inhibited widespread implementation thus far. Given the pervasive use of fuelwood and the long-run supply problems to be faced, conservation of this resource should be pursued further. Since woodstove implementation programs have had difficulties, a critique of past projects must be realized now in order to properly direct the program.

The Industrial Sector

2.19 Structure of the Sector. The Ecuadorian industrial sector is a relatively small component of the country's economy. Ecuadorian industry is characterized by predominantly light and small manufacturing activities and contributed only 17% to the GDP in 1982. Major industries, by value added in 1982 are: food, beverage and tobacco (47%); textiles (21%); and mineral products (11.0%); followed by smaller contributors such as: paper and printing (5%); wood products (5%) and chemicals (5%). More than 80% of manufacturing employment and value added in industry is located in the Provinces of Guayas and Pichincha. Past development plans called for rapid industrialization, but the current outlook is not as optimistic as it was during the oil boom in the 1970s.

2.20 Energy Consumption. In 1984, the industrial sector was the third largest consumer of energy in Ecuador (17%), after the transport and household sectors. Major consumers of energy are the agroindustries (42%) and the mineral industries (25%) (mainly cement). DNH assigns a quota of petroleum fuels to industrial consumers as a measure to avoid excessive consumption of subsidized petroleum.

8/ Kerosene 15%, LPG 9%, and low octane gasoline 3%.

2.21 As a consequence of the sharp increase in petroleum supply in the early 1970s and low domestic prices, the share of petroleum products used in industry increased from 50% in 1970 to 68% in 1984. Paralleling this evolution, the share of non-commercial energy in industry fell from 42% in 1970 to 20% in 1984. Electricity oscillated in the range of 7% to 12% during the same period. The heavy dependence of the industrial sector on hydrocarbons is reflected in the fuels utilized: fuel oil (43%), diesel oil and kerosene (25%), bagasse (20%) and electricity (12%). Table 2.6 shows energy consumption by select industries in Ecuador.

Table 2.6: ESTIMATED ENERGY CONSUMPTION OF SELECTED INDUSTRIES IN ECUADOR, 1984 (KTOE)

Industry	Bagasse	Electricity	LPG	Kerosene	Diesel Oil	Fuel Oil
Cement						
LCN	-	13.9	-	-	-	157.3
Selva Alegre	-	4.7	-	-	n.a.	32.0
Chimborazo	-	3.0	-	-	n.a.	32.7 a/
Sugar b/						
San Carlos	34.0	-	-	-	n.a.	0.9
Valdez	29.2	-	-	-	n.a.	3.0
Aztra	24.1	-	-	-	n.a.	1.3
Textile						
Continental	-	0.2	-	-	0.2	1.1
Other						
CRIDESA (glass containers)	-	1.9	1.3	3.0	0.1	5.8
INCASA (paper)	-	0.4	-	0.6	0.6	3.3
ANDINA (brewery)	-	0.01	-	-	0.002	0.2

a/ Includes 150 t/d cement capacity based on wet process.
b/ 1983 data.

Source: Mission estimates and DECON study.

2.22 Possibilities for Encrgy Conservation. Mission visits to selected plants representative of the cement, sugar, textiles food and beverage and other industries suggest that there is considerable room for increasing efficiency in the use of commercial and biomass fuels in Ecuadorian industry. Although pricing remains the essential tool in conservation, specific cases have shown that with modest investments -- mainly in the form of expert advice at the plant, considerable amounts of energy could be saved.

2.23 The two major consumers of petroleum products are refineries and cement industries. Changes in refinery operations could save diesel oil used in fuel oil dilution by consuming mostly residual oil at higher temperatures. Potential savings of 20 ktoe per year (roughly US$3.9 million per year at US$27 per bbl.) could be achieved with an investment requirement of US$4 million. 9/ Cement industries have a range of fuel oil consumption in their kilns of 850-1300 kcal/kg-clinker. Overall, if the energy consumption of the three largest cement companies (96% of total output) could be reduced to 850 kcal/kg-clinker, savings of about 28 ktoe could be achieved. Typical investment requirements are around US$300/toe/year; thus, the above savings require some US$8 million. The mission analysis also suggests an opportunity to save fuel oil in the Chimborazo cement plant (150 tpd) by discontinuing the energy intensive wet process.

2.24 With regard to steam raising for industrial purposes, by reducing the direct use of diesel oil/kerosene as a boiler fuel and a fuel oil dilutant, a potential saving of 116 ktoe per year (roughly US$22 million per year at US$27 per bbl.) could be achieved with an investment requirement of US$11.6 million. 10/ A high potential exists (about 192 MW) for replacing diesel in power generation with hydro in Guayaquil, and its implementation will be carried out by INECEL within the next five years.

2.25 The major consumers of biomass fuels in Ecuadorian industries are the sugar mills. The operating regime of the mills depends on the availability of cane, and therefore of bagasse, and on equipment failures. Since there are practical uncertainties associated with both factors, fuel oil is employed as a backup fuel. By reducing fuel oil consumption in sugar mills to 0.1 gal/ton of sugarcane through (a) the use of surplus bagasse resulting from an improved cane supply, (b) burning dryer bagasse, and (c) improving the bagasse boiler, a potential saving of 4.7 ktoe per year (roughly US$1 million per year at US$27 per bbl.) could be achieved with an investment requirement ranging from US$3.3-5.8 million. 11/

The Transport Sector

2.26 Highways are the predominant and fastest growing mode of transport in Ecuador. The extension of paved roads is about 6,000 km with a total highway network, including gravel and earth roads, of about 35,000

9/ Estimated at 15% of petroleum fuels used by the refineries themselves at US$200/toe.

10/ Estimated at 40% of diesel/kerosene fuels used in industry with minimum investment (US$100/toe).

11/ Range estimated on the basis of the cash flow generated by the savings of fuel, for project lifetimes of 10-20 years, discount rates of 12-20% p.a.

km. Water transport (mainly maritime) is the second largest mode of transport, and rail transport is of limited significance and has been declining. As a net oil exporter, Ecuador moves the bulk of its crude output via the Transecuadorian pipeline.

2.27 Reliable vehicle fleet statistics are lacking in Ecuador. It is estimated that the vehicle fleet grew at 12% per annum during 1972-1982, to about 264,000 vehicles by 1982. Light vehicles seem to predominate, accounting for almost 90% of the fleet. Heavier vehicles are evenly split between buses and trucks, each with approximately 5% of the total fleet. Most of the vehicles (65-70%) are registered in the provinces of Pichincha and Guayas.

2.28 Energy Consumption. The transport sector is the single most important user of energy in Ecuador (consuming 1751 ktoe in 1984). Liquid fuels used in transport consumed 50% of commercial energy and 54% of total liquid hydrocarbon fuels. It is estimated that road transport consumes 66% of the energy used by the sector (gasoline 86% and diesel oil 14%), waterways 23%, air transport 7%, the pipeline 3%, and the railway system 1%.

2.29 Energy consumption in road transport is dominated by freight transport (including pipelines) with 43% of total volume, light vehicles (predominantly for private passenger transport) with 29%, buses with 19% (interurban 13%, urban 6%) and taxis with 9%. Overall public passenger transport (taxis plus buses) consumed 28% of the total volume of fuel used in the transport sector.

2.30 Energy Conservation Possibilities. Energy conservation in the transport sector can be attained in two ways: (a) through inter-fuel substitution, and (b) by increasing the efficiency of the transport system.

2.31 Substitution of Diesel Oil for Gasoline. Dieselization of transport in Ecuador is very limited compared with what it would be if the prices of gasoline and diesel oil reflected their economic value and the higher efficiency of diesel engines were recognized. Analyses of prospects for intensified dieselization of the Ecuadorian vehicle fleet have been conducted by INE under various technical cooperation programs such as with the EEC and the French Energy Agency (AFME).

2.32 The INE/EEC study revealed that savings of 14-35% in the transport sector could be achieved during 1981-2000 by adopting various measures of energy conservation, including dieselization. The study analyzed two scenarios: (a) a high consumption case based on a "status quo" situation and (b) a low consumption case which includes intensified dieselization and other measures. Details about this study are presented in Annex 5.

2.33 The INE/AFME study suggests that the structural changes in the vehicle fleet in the low consumption scenario - essentially a dieselization of the gasoline-fueled fleet -- have very strong economic merit. The highest IRRs are obtained for the public passenger transport fleet (microbus and bus) at 59% per year; trucks follow with an IRR of 39-50% per year, and taxis showed the lowest IRR with 21% per year. Table 2.7 shows details on the economics of dieselization.

Table 2.7: ECONOMICS OF DIESELIZATION
(Switching from gasoline to diesel powered vehicles)

Vehicle Type	Vehicle Lifetime (months)	Annual Mileage (km)	Incremental Capital Cost (US$)	NPV at 20% p.a. (US$)	IRR (% p.a.)
Taxi	84	51,600	900	16	20.6
Microbus (Buseta)	120	57,600	2,000	3,075	58.8
Bus	120	57,500	2,700	4,123	58.6
Average Truck	120	57,600	1,800	1,232	38.6
Heavy Truck	108	63,360	2,700	2,929	49.5

Source: French Energy Agency (AFME) study and mission estimates.

2.34 Substitution of CNG for Gasoline and Diesel Oil. Compressed natural gas could play a small but important role in gasoline and diesel oil conservation in Ecuador in the future (see para. 4.7). The gas netback value and NPV of a potential project to convert some 3,500 public transport vehicles (taxis and buses) in Guayaquil confirmed, on a preliminary basis, the economic merits of the concept. The INE/AFME study also suggested that a limited experimental program for CNG in transport could begin based on associated natural gas from the Oriente. This would expedite the CNG learning process in Ecuador, thereby facilitating the implementation of any future CNG transport program at a later date, such as the prospective Guayaquil project.

2.35 Substitution of Electricity for Liquid Fuels in Transport. The idea of implementing electric urban transport systems in Guayaquil and Quito has been discussed for some time. Interest in these schemes is likely to be rekindled as new hydroelectricity capacity becomes available. Analysis conducted under the auspices of INE correctly assesses these schemes by indicating that the liquid fuel savings achieved would not justify the high investment required. Uncertainties and obstacles to electrification of urban transport in Ecuador include: the electricity tariff, the high capital cost and foreign exchange requirements, and the current socioeconomic organization of public transport in Guayaquil and Quito. Consequently, electrification of urban transport systems in Ecuador does not seem to be a priority item in the country's list of energy initiatives.

2.36 Increasing Transport Systems Efficiency. The current disorganized system of predominantly individual operators, along with other factors, is not conducive to energy efficiency in transport. The proper coordination of transport companies would result in more efficient energy use.

2.37 Freight Transport System Management. Measures to promote back-hauls should be implemented through systems for gathering and disseminating freight information which could involve a clearinghouse of freight needs in Ecuador, and to other countries. Freight consolidation terminals could also be implemented in Ecuador to improve freight load management. Thus, the current capacity utilization of freight transport would increase from 50% (i.e. empty back-hauls) to a more energy/economically efficient level of at least 70%.

2.38 Public Transport System Management. Besides the coordination problem mentioned above, the public transport system is characterized by gasoline fueled and low unit capacity buses. These should be replaced by high unit capacity buses operating with high loads and using diesel fuels. Another measure which could improve system efficiency is in bus design improvements. New bus body designs could include: 12/ (a) less weight with new, lighter materials; (b) two doors, as opposed to the single door bus design which currently predominates in the fleet; (c) more room for passengers to move in and out of the bus; and (d) a fixed seat for the fare collector, and the introduction of fare collection by a person other than the bus driver.

2.39 Rationalization of urban and inter-urban passenger traffic could contribute much to improving energy efficiency in the public transport sector. This could be accomplished through a combination of initiatives, such as: (a) service planning, including better route planning; (b) extension of the staggered working schedule that already proved its worth with civil servants' single work journey, to other workers' categories; (c) promotion of shift from private to public transport by offering a better service to middle class residential districts/suburbs, charging higher tariffs, if necessary; (d) promotion of a certain measure of standardization of private passenger vehicles, including energy efficient vehicles, via import duty discrimination and other measures; (e) recovery of urban congestion costs via parking charges, zonal fees, etc.; (f) prohibition of private passenger traffic in certain urban areas (e.g. core of major cities) and other physical restrictions of traffic; and (g) improvement in toll gate operations (e.g. higher tolls or no tolls to avoid traffic congestion).

12/ In this context the experience of the double deck buses operated by the municipality of Quito should provide useful information.

2.40 Another measure to increase energy efficiency in freight and public transport relates to improved maintenance of equipment. A combination of well equipped, well staffed repair shops jointly utilized by various companies or cooperatives should be implemented.

Recommendations

2.41 Besides changes in the pricing policy, the mission considers that the GOE should take the following actions to optimize energy use in Ecuador:

Household

(a) Analyze and compare the relative merits of (i) subsidizing kerosene and (ii) a reforestation program for energy purposes.

Industry

(a) Revise the current quota system provided by DNH for petroleum fuel consumers. The revision should be based on energy audits of requesting industries conducted by accredited organizations and supervised by INE.

(b) Finance energy conservation audits and energy measuring and savings equipment via national and multilateral sources.

(c) The Ministry of Industry should use the results obtained in the audits in order to assign the benefits included in the Ley de Fomento.

(d) Promote the Non-Conventional Energy Resources Law which contains fiscal and credit measures for the financing of energy savings and conservation.

(e) Review INE's role and past efforts in industrial energy conservation to reorient its training efforts toward direct services to industry, and assess its promotional campaign to fully and effectively utilize its resources.

Transport

(a) By using fiscal, credit, and other regulatory measures, promote structural changes in fleet composition favoring end-use energy efficiency in transport, improve freight system organization and management, improve public transport system organization and management.

(b) Improve institutional coordination and execution of energy efficiency measures in the transport sector, among the Provincial Councils, MOP, DNH, INE and other bodies involved.

III. PETROLEUM

Background

3.1 The key issues in the petroleum subsector for Ecuador are: declining oil reserves, establishing an appropriate development and production strategy, the supply/demand imbalance of petroleum products, determining the future role of the State Petroleum Corporation (CEPE), and petroleum product pricing (analyzed in Chapter II).

3.2 The principal institutions and companies active in the petroleum industry in Ecuador are the State Petroleum Corporation (CEPE), the Department of Hydrocarbons (DNH) of the Ministry of Natural Energy Resources (MRNE), and the Ecuadorian subsidiary of Texaco, which operates in a consortium with CEPE. The Hydrocarbon Law, the Law of CEPE, and the law of bidding and contracting are the principal documents of petroleum legislation that affect the administration and exploitation of hydrocarbons. The MRNE is responsible for implementation of hydrocarbon policies and the DNH is the technical-administrative branch of MRNE that controls all hydrocarbon operations.

3.3 CEPE is the owner of 62.5% of the consortium with Texaco, which produced over 85% of total oil output in Ecuador in 1984; it is also owner of 50% of the Transecuadorian pipeline 13/ -- together with Texaco until the end of 1985 -- and associated storage and export terminal facilities. By the end of 1985, CEPE will become the sole owner of the pipeline and Texaco will continue operating it under an existing agreement. Most of the country's refining capacity (95,000 bbl per stream days) is owned by CEPE, and it also owns all of the gas-processing plants, product pipelines, and distribution terminals. CEPE has a monopoly on internal marketing of petroleum products but contracts with others for most product transport other than by pipeline. It sells its own share of crude oil production, and the refinery's surplus of refined products in international markets. IBRD Map No. 18930R shows the oil pipelines network as well as other modes of petroleum transport.

3.4 City Ecuadorian Production Co., a small, U.S.-based private holding company, produces in consortium with CEPE from three fields in the Oriente. City, which is operator of these fields, currently produces about 1.8% of the total Ecuadorian oil production (4740 bd).

13/ This line, which was completed in 1972 and has a present capacity of 300,000 bd, starts at an elevation of 299 m and reaches a maximum height of 4,064 m where it crosses the Andes near Quito. It is approximately 500 km long, reaching from the Oriente pumping station at Lago Agrio to the Balao terminal, on the coast near Esmeraldas.

3.5 Exploration for hydrocarbons in Ecuador began in the early 1900s along the Pacific coast. The first significant discovery was made by Anglo-Ecuadorian Oilfields Ltd. in the 1920s near the tip of the Santa Elena Peninsula (see IBRD Map No. 18930R) where good quality oil of about 35° API was found. From more than 100 million bbl of oil from Santa Elena produced to date, current production is less than 1,000 bd from some 480 wells combined; this output is probably not economic due to high operating costs 14/ (US$28.63/bbl in Santa Elena vs. US$0.62/bbl in the Oriente as a result of low production (less than 3 bbl per day per well) and old producing equipment which is expensive to maintain in operating condition. Nevertheless, the effect of continued oil production from the Peninsula fields is now negligible compared to that from the Oriente where almost all of Ecuador's petroleum production originates.

3.6 Hydrocarbon exploration studies were performed as early as 1921 in the Oriente. But it was not until 1967 that the first well was drilled by Texaco-Gulf (Lago Agrio 1) leading to the discovery of oil in commercial quantities. Discoveries in the Sacha and Shushufindi oil fields in the Oriente followed in 1969. Between 1967 and 1984, a total of 105 exploration wells were drilled, of which 50 exploration wells resulted in discoveries of commercial quantities of oil, indicating the very high success rate of 47.5%. The most common gravity of crude oil found in the Oriente is 28° API, a moderate grade of crude.

Petroleum Exploration and Development Activities

Current Reserves

3.7 Ecuador's petroleum reserves are virtually all located in the Oriente region, where proved reserves amount to nearly one billion barrels. As of January 1, 1985, the ratio of proved reserves to 1984 oil production resulted in a reserves/production ratio of almost 10 years. If probable reserves are considered along with proved reserves, the reserves/production ratio is sufficient for over 16 years' supply. A breakdown of the proved and probable petroleum reserves is shown in Table 3.1. DNH will change the probable reserves volume by 218 million bbl obtained from secondary recovery in Shushufindi/Aguarico to the category of proved reserves at the time of its next reserves revision which is still undetermined. When secondary recovery begins in Sacha in July 1986, 167 million bbl of probable reserves will be changed to proved reserves.

14/ These are direct lifting costs and do not include any depreciation, administration, or crude oil transportation costs.

Table 3.1: ORIENTE OIL RESERVES (as of 01/01/85)
(MMBBL)

	CEPE-Texaco	CEPE-City	CEPE	TOTAL
Proven	697.526	12.440	217.949	927.915
Probable	529.979 a/	2.691	53.784	586.454
Total	1227.505	15.131	271.733	1514.369

a Includes 385 MMbbl secondary recovery.

Source: CEPE.

Petroleum Exploration

3.8 The legislation revising the Hydrocarbon Law in August 1982 to attract private investors has been successful. This is evidenced by the recent signing of exploration service contracts with Occidental Petroleum Company, Exxon and Belco, and negotiations with BP, Conoco and Texaco. The combined minimum exploration obligations of Occidental, Exxon and Belco, however, are sufficient to replace Ecuador's reserves. The GOE should continue to attract private capital companies in exploration and expand to more area service contracts. Exploration in the Sur-Oriente, south of the Oriente producing fields, has been very spotty despite the impressive successes of Occidental immediately adjacent to the border in Peru under what appears to be identical geological conditions. This is to a large extent because most of the Sur-Oriente lacks infrastructure in the area. However, the GOE is considering opening these areas to foreign investors.

3.9 Although the Government's position in encouraging private investors in exploration by offering attractive CEPE areas, monitoring CEPE's investment closely, and insisting on elimination of wildcat drilling by the Corporation is commendable, the mission concluded that CEPE should continue in low risk exploratory work. In view of CEPE's good discovery rate (62.5% from 1975 thru 1984), and since production resulting from private company exploration investment may not start until the early 1990s — assuming further commercial discoveries — the Government should support sufficient exploration investment by CEPE in known structures so as to help ensure an adequate reserves/production ratio, and sufficient oil supplies and exports in the short to medium term. In addition, Ecuador will have to reduce its oil exports by 1989 unless new discoveries are made (see para. 3.13). CEPE has the means and capability to conduct an exploration program and as a result will gain more experience and strength with private companies. CEPE can also conduct seismic surveys, geochemical prospecting, and geological studies including evaluation of possible sedimentary traps, in relatively unknown but attractive areas, to assist in the promotion of new service contracts in these areas by private companies. The continuation of an adequate level of exploration activity by CEPE will also provide the company with a core of experienced exploration staff when foreign companies complete their exploration programs.

3.10 Declining Oil Reserves. The mission estimates that roughly 15 new exploration wells per year must be drilled in the Oriente in order to maintain Ecuador's reserves/production rate. Instead, CEPE is limited to drilling only one well in 1985 with a combined minimum exploration obligation from Occidental, Exxon and Belco of only nine exploratory wells within a period of four years. Just to hold the future reserve/production ratio constant during the next ten-year period demands that roughly 90 to 100 million bbl of new oil reserves be discovered each year.

3.11 Assuming the same discovery rate as in the Oriente, CEPE should drill 18 exploration wells during the next five years just to replace their depleted oil reserves. As a minimum program, CEPE should be drilling four exploration wells each year during 1985 and 1986. During 1987 and thereafter, a minimum of five exploration wells per year should be drilled by CEPE. The GOE limit on one exploratory well in 1985 by CEPE is a result of fiscal policy and the government's attitude on leaving all exploration in the hands of foreign investors. The mission concludes that with some reorganization and adequate contracted assistance, CEPE can effectively conduct an exploration program of this magnitude.

Petroleum Production and Secondary Recovery

3.12 Production of crude oil in Ecuador increased from 3,700 bd in 1971 to 208,800 bd in 1973, and remained relatively steady thereafter, to 266,700 bd in 1984. From 1985 thru 1988, oil production rates are predicted to be higher than the average 1984 daily rate, reaching roughly 300,000 bd by the end of 1985.

3.13 Unless new discoveries are made immediately or new fields are found economic for secondary recovery, Ecuador will have to start reducing its oil exports by 1989. After 1989, a serious decline in production rates is indicated, even with constant production rates being maintained in Shushufindi-Aguarico and Sacha as a result of water injection into those fields. If the growth of internal demand for petroleum products continues at its present rate of 5.5% p.a., 15/ the mission considers that projected crude production will not be sufficient to maintain crude exports beyond 1988 at the conservative 1983 levels of about 50.8 million bbl p.a. Table 3.2 compares the internal demand growth effect, based on actual 1983 volumes of internal market and export crude oil, with the prediction of future production from existing fields. Annex No. 6 provides a production profile to the year 1994.

15/ DNH considers a demand growth rate of 3.5 to 4% more realistic.

3.14 New fields must be discovered and quickly put on production to offset the rapid declines predicted after 1988, or effective, aggressive applications of secondary recovery methods should be intitiated as rapidly as possible in all fields where the reservoir characteristics indicate these methods to be feasible. This at least will partially offset the production decline after 1988, but only new oil discoveries will provide replacement oil reserves to meet long-term future requirements. If the findings of new fields and/or secondary recovery do not succeed, exports must be reduced by the amounts shown each year as a deficit in the last column of Table 3.2.

Table 3.2: PETROLEUM PRODUCTION, REQUIREMENTS AND SURPLUS (DEFICIT) IN MMBBL

Year	Crude Oil for Internal Market a/	Crude Oil for Export b/	Total Required	Total Predicted Production	Difference
1983	35.294	50.811	86.105		
1984	37.235	50.811	88.046		
1985	39.283	50.811	90.094	96.496	6.402
1986	41.444	50.811	92.255	97.701	5.446
1987	43.723	50.811	94.534	96.207	1.673
1988	46.128	50.811	96.939	96.936	-
1989	48.665	50.811	99.476	93.280	(6.196)
1990	51.341	50.811	102.052	89.318	(12.734)
1991	54.165	50.811	104.976	85.005	(19.971)
1992	57.144	50.811	107.955	82.728	(25.227)
1993	60.287	50.811	111.098	79.975	(31.123)
1994	63.603	50.811	114.414	77.628	(36.786)
Totals 1985 thru 1994:			1,013.783	895.274	(118.519)

a/ CEPE forecast.
b/ Assumed constant.
Source: DNH and mission estimates.

3.15 Government strategy on petroleum production has been dominated by regulations which control output because of: technical reasons involving the protection of producing oil fields, previous agreements with other OPEC member countries, limited infrastructure capacity over the next several years, and conservation purposes. The mission concluded that, without damaging oil fields, a substantial increase in crude production might be achieved from existing producing wells provided that a sufficient level of exploration is ensured to at least maintain the reserves/ production ratio in the medium and long-term. This would provide revenue that could be used in part for additional exploration, and other related investments.

3.16 Following the mission's recommendations, the Government has already agreed to increase production from the Shushufindi oil field by 10,000 bd. Despite the strong technical reasons presented by the mission and the consortium engineers, the Government has not yet authorized an increase of 20,000 bd from the Cononaco oilfield, claiming this would exceed the accepted practice of limiting the field reserves/production ratio. The limit on production set for the Cononaco field implies a foregone income of about US$200 million per year to CEPE.

3.17 Production from fields operated by CEPE will increase by about 10,000 bd by end 1985 due to the recent discovery of an extension of the reserves of the Libertador oil field and the planning of additional wells which could be equipped rapidly with materials available in stock. Installation of artificial lift equipment should be initiated as soon as possible in Cononaco and in fields where most of the investment required has already been made.

Heavy Crudes

3.18 Since the petroleum reserves have been declining steadily, heavy crudes offer a possible long-term alternative for Ecuador. Petro-Canada experts estimate Pungarayacu heavy oil reserves at some 3.5 billion bbl of 8-15° API oil, adjacent to the town of Tena in the Oriente (see IBRD Map No. 18930R). It is clear, however, that large-scale development of heavy oil would not be feasible in the short or medium-term, mainly because of the high cost of infrastructure development. From a field visit in October 1982, Petro-Canada concluded that mining methods were not feasible and in situ recovery methods employing heat would be very expensive. CEPE plans only limited drilling of six shallow wells during the current year to determine whether an inexpensive method can be found for producing from some of the wells. Due to limited funds and greater priorities in the petroleum subsector, future activities here should only be taken in conjunction with private companies. The mission agrees with the Ministry and CEPE position that only limited experimentation should be continued to determine costs and to anticipate any problems for future commercial exploitation.

Petroleum Supply

3.19 Refinery Strategy. Ecuador does not plan to emulate the larger OPEC nations in attempting to refine on a large scale for exports. This appears to be a prudent decision, considering the uncertainty of the refineries in the Caribbean, unstable petroleum market, the great excess of refining capacity worldwide and competition for export markets. Ecuador's policy is only to expand refining capacity as required to balance local production with demand.

3.20 The country's strategy to develop the three existing refining centers in parallel is a sound policy decision. Each refinery is well placed to supply a specific market and at the same time, there are linkages between these principal market areas. However, it should be noted that available capital has priority needs in oil exploration and development where it has a much higher return. Consequently, the GOE should promote joint ventures in refinery investments.

Refining Facilities

3.21 Ecuador has four refineries yielding a total capacity of 95,000 barrels per operating day which are located in three refining centers: the Santa Elena Peninsula, Esmeraldas, and in the Oriente. The largest one (capacity 56,000 bd) is at Esmeraldas and is wholly owned by CEPE; the three older refineries are operated by Anglo-Ecuadorian and Repetrol in the Santa Elena Peninsula (combined capacity 38,000 bd) and Texaco in the Oriente (capacity 1,000 bd). The Esmeraldas refinery receives Oriente crude through the Transecuadorian Pipeline operated by CEPE, while the others are located near the oil fields (see IBRD Map No. 18930R).

Supply/Demand Imbalance

3.22 Despite the increase in refining capacity that came about with the commissioning of the Esmeraldas refinery in the mid-1970s, most refined products (except fuel oil) are in deficit. Because of this imbalance in product mix, the low-value surplus fuel oil is being exported while higher-value light and middle distillates (gasoline, diesel, jet fuel, kerosene) are being imported.

3.23 Currently, the major shortfall that must be made up by imports is in gasoline, as shown in Table 3.3. Kerosene/jet fuel is close to being in balance, but diesel and LPG also fall short. The 1990 situation, with the Esmeraldas refineries expanded to 90,000 bd and the proposed new Amazonas refinery (para. 3.47) in operation, shows a reduced -- but still positive -- shortfall in gasoline and diesel, and an increased shortfall in LPG. Beyond 1990, the light product shortfalls are exacerbated as demand grows.

3.24 After the expansion of Esmeraldas and completion of Amazonas, the next logical step in refinery development will be to modernize the Santa Elena Peninsula refineries. Although increases in petroleum prices may result in reductions in future demand, it is unlikely that such a reduction would be sufficient to justify modification of plans now in development. Plans for further refinery expansion should be considered very carefully, taking into consideration the perspective of the world refinery industry, and investment priorities in the petroleum subsector.

Storage

3.25 Considering that all crude deliveries to Esmeraldas are made by pipeline and backed up by nearly 3 million bbl of export crude tankage, the 18 days of crude oil storage at Esmeraldas is adequate. Likewise, 30 days of distillate storage is adequate, but 28 days of fuel oil storage is tight since deliveries depend on ship arrivals.

3.26 Major storage additions are being made at many of the terminals as pa~t of future refinery expansion. In particular, increases in fuel oil storage for the Esmeraldas and Santa Elena refineries. The total storage planned will consist of about 2.3 MM bbl at refineries and 1.9 MM bbl at terminals. This would be sufficient supply for 1 month at each site.

Table 3.3: SURPLUS (DEFICIT) OF PRODUCTION OVER DEMAND IN BBLS

	1980	1985 a/	1990 b/	1995 b/	2000 b/
LPG Demand	1,157	2,200	3,395	5,256	7,373
Production	844	1,285	1,949	1,949	1,949
Surplus (Deficit)	(313)	(915)	(1,446)	(3,307)	(5,424)
Gasoline Demand	10,612	9,960	12,921	14,710	16,206
Production	8,415	7,630	11,861	11,861	11,861
Surplus (Deficit)	(2,237)	(2,360)	(1,060)	(2,849)	(4,345)
Kerosene Demand	2,588	2,390	3,249	4,161	4,964
Production	2,267	2,390	3,560	3,560	3,560
Surplus (Deficit)	(321)	-	311	(601)	(1,404)
Diesel Demand	6,138	6,380	9,892	13,104	16,170
Production	5,605	4,899	8,685	8,685	8,685
Surplus (Deficit)	(533)	(1,481)	(1,207)	(4,419)	(7,485)
Fuel Oil Demand	5,678	6,700	10,184	14,673	20,404
Production	14,876	13,397	18,326	18,326	18,326
Surplus (Deficit)	9,198	6,697	8,142	3,653	(2,078)
Jet Fuel Demand	1,140	1,100	1,351	1,659	2,044
Production	1,098	930	1,553	1,553	1,553
Surplus	(42)	(170)	202	(126)	(49)
Total Fuels Demand	27,313	28,730	40,990	53,582	67,160
Distillate Fuel Deficit	3,446	4,926	3,713	11,302	20,785

a CEPE operating plan.
b/ CEPE demand forecast with expansion of Esmeraldas and commissioning of Amazonas refinery.

Source: CEPE and mission estimates.

Institutional Issues

Petroleum Legislation and the Role of CEPE

3.27 The role of CEPE must be redefined and the Government must take actions to implement its decision. CEPE is not able to function as an efficient oil company mainly because of constraints such as price ceilings, limited exploration involvement, and insufficient autonomy permitted by the petroleum legislation. Under these legal stipulations, it will be very difficult for CEPE to develop experienced, dedicated individuals at all levels who will strive to improve the efficiency of CEPE and make it competitive with other companies in similar businesses. As a consequence, CEPE may lose its most qualified staff in considerable numbers to the benefit of private companies planning to participate in Ecuador's petroleum production. The Government of Ecuador will have to depend more and more on private capital companies to find and produce the oil which Ecuador will need in the years to come unless drastic changes are made in existing petroleum legislation, especially in pricing and CEPE's autonomy to function as an efficient oil company.

3.28 The Government is keenly aware of the need to improve CEPE's operating efficiency. Thus far, however, it has limited its actions to controlling the scope of CEPE's activities by curtailing the Corporation's investments, especially in exploration and seeking ways to surmount the problem of procurement delays.

3.29 A serious constraint in the development of Ecuador's petroleum sector is the fact that the Hydrocarbon Law stipulates that domestic petroleum product prices have a production cost ceiling (see para. 2.4). Depletion allowances are not included in the formula provided for in the Law, and opportunity costs are not considered either. The MRNE establishes prices for sales to consumers of all hydrocarbon products, taking into account the cost of refining, cost of tranport, storage and distributing all taxes that apply, and a resonable profit for distribution. These prices will be revised whenever modifications in costs justify such revision.

3.30 The efficiency of CEPE's operation is hampered by conflicts in day-to-day matters, and its autonomy to function as a petroleum corporation should be assessed. According to the Law of CEPE, the General Manager of CEPE can authorize expenditures or investments only up to about US$5,000 equivalent. The Minister can authorize up to US$10,000, and beyond that point it must be presented to the Board of CEPE. 16/

3.31 The deep-seated legal rigidities under which CEPE and other state enterprises operate, and the bureaucratic delays -- aggravated in CEPE's case by the political activities of a large number of unions that operate within the Corporation -- prevent CEPE from operating efficiently. These, rather than quality of personnel, are the main problems facing CEPE, as evidenced by the fact that many of it's staff members have held similar positions in the CEPE-Texaco consortium and have operated efficiently there. Consideration ought to be given to achieving operational improvements by applying the joint venture concept -- as in the CEPE-Texaco consortium -- to CEPE's existing operations in its own blocks. The consortium which operates mainly as a private company is not affected by the legal rigidities that inhibit CEPE's efficiency.

16/ Since the Assessment Mission, this limit has been extended to US$150,000.

3.32 MRNE and CEPE are tackling institutional problems, some of which might require changes in the Hydrocarbon Law. They are also seeking improvements in procedures -- especially in procurement, where delays are causing enormous costs to CEPE and the economy. Officials indicate, however, that, since the situation has become institutionalized over a long period, basic reforms will not be achieved quickly. The mission believes that if at least the main procurement bottlenecks can be eliminated, significant progress will have been made. 17/

3.33 The organization of DNH, the technical and administrative branch of MRNE responsible for hydrocarbon activities within Ecuador, is essentially duplicating activities carried out by CEPE. In effect, the DNH has technical groups doing the same studies, technical investigations, financial analyses, and statistical reports that CEPE does. MRNE should make a very clear distinction between establishing national hydrocarbon policies, and the actual operations by CEPE and other companies within the Government's petroleum policies, but allowing them the freedom of decision to operate in the most efficient manner. DNH should concentrate on executing policy while CEPE should increase its autonomy to concentrate on petroleum operations effectively.

CEPE's Finances

3.34 CEPE's ability to operate as an oil company is seriously impeded by its lack of financial autonomy. Its investment resources have come mainly from earmarked oil tax revenues. The Corporation's share of these revenues has averaged the equivalent of about US$48 million p.a. over the past six years; its sources of investment funds have been largely restricted to this source and to internal generation of funds. The mission concluded that the Government should outline a financial strategy for CEPE that would include investment and resource requirements linked to an overall policy guiding CEPE's role in the medium- and long-term.

3.35 CEPE shold have enough resources to finance a sound investment program developed jointly with DNH (paras. 3.37 - 3.44). The mission considers that a detailed financial analysis of CEPE and an analysis on the distribution of oil revenues within the country's macroeconomic context should be carried out.

3.36 There are 14 different taxes on petroleum and petroleum royalties and 21 different recipients. The main petroleum tax recipients are the Central Government Budget, INECEL, CEPE, the National Defense

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17/ Since the Assessment Mission, the GOE has taken steps to identify these procurement bottlenecks. In addition, the World Bank is becoming directly involved in helping in the area of institutional reforms through a recently approved loan for a public sector management project.

Board, BEDE, and the Local and Provincial Governments. In 1982, petroleum taxes amounted to almost US$1.5 billion, 18/ equivalent to 63% of total tax income. Although there is a trend towards reducing of earmarking, 65% of oil revenues are still earmarked. This situation contributes to undermining efficiency incentives within the favored entities (e.g., INECEL, BEDE, CEPE).

CEPE's Investment Program

3.37 Until recently, CEPE had an ambitious investment plan covering practically every aspect of the oil industry, from oil exploration to natural gas, to fertilizer and polypropylene plants. As formulated, the plan would have absorbed about one-half of total public investment in the period 1985 through 1988. Since then, the GOE has reduced the investment program. The Atahualpa refinery has been deferred and the lubricant, polypropylene and gas projects, and fertilizer plant are on hold, waiting for a suitable private sector partner without whose participation the projects will not be undertaken. Table 3.4 provides a summary of CEPE's previous and recommended investment program.

Table 3.4: CEPE'S INVESTMENT PLAN, 1985-1988
(US$ Million 1984)

	Previous Plan	Distribution of Previous Plan	Recommended Plan	Distribution of Recommended Plan	Recommended as % of Previous Plan
		(%)		(%)	
Exploration	92.8 a/	5	170.0	19	205
Development	332.0 a/	17	494.0	54	145
Refineries:					
Esmeraldas	123.0	6	123.0	13	100
Amazonas	23.0	1	23.0	3	100
Atahualpa	941.2	49	0	-	-
Basic Lube Oil Plant b/	51.1	3	0	-	-
Transport & Storage	97.4	5	97.0	11	100
Petrochemicals b/	61.5	3	0	-	-
Fertilizer Plant b/	210.0	11	0	-	-
Total	1,932.0	100	907.0	100	47

a/ 1985 plan projected for four years.
b/ Total cost of project, not only funds to be invested in 1984-1988.
Source: CEPE, and Public Investment and Energy Assessment Mission estimates.

18/ Using the 1982 exchange rate of 1 US$ = 30 sucres.

Exploration and Oil Field Development

3.38 During the transition period in which the Government is taking a hard look at the role of CEPE, the Corporation is being limited to preparing an investment program of US$106 million just for 1985. Of this total, only about US$23 million is allocated for exploration and US$83 million toward oil field development. Annex 7 provides a detailed breakdown of the exploration and production investment program for 1985.

3.39 Exploration. CEPE is allocated only a small fraction for exploration drilling. The Corporation is spending most of its 1985 exploration allocation on seismic surveys, and only US$2.4 million for exploration drilling -- one well by CEPE, and CEPE's participation in one well to be drilled by Texaco. This is a drastic reduction from the CEPE exploration program contained in the Five-year Plan 1984-1988 that was prepared in October 1983, in which twelve exploration wells had been projected to be drilled by CEPE during 1985. Although CEPE has not prepared a program for development after 1985, it is anticipated that the number of development wells to be drilled and the overall development budget during each of the next few years will be similar to that for 1985. This is a sharp drop from the 5 exploration wells per year recommended by the mission to replace the CEPE oil reserves to be produced (see para. 3.11).

3.40 Which CEPE's previous exploration plan may have been too ambitious, its current plan is too modest. Unless CEPE continues with a reasonable level of exploration activity, it cannot develop and maintain a reliable exploration staff. The Company's exploration program needs to be increased by about US$20 million per year and redirected to the northern Oriente region where CEPE's previous efforts have been successful.

3.41 Oil Field Development. Development of existing oil fields is clearly the most profitable investment that the Government can undertake. A previous World Bank mission investigated three possible investment scenarios to the year 1990 and estimated the possible benefits associated with each one. 19/ Total investments for every year from 1985 to 1990 and petroleum production as a function of investment levels appear in Annex 8. The cash outlays of the low case amount to US$245 million (1984 prices); the expected output to 541 million barrels. The total outlays of the high case amount to US$716 million (1984 prices), the total production of the high case to 779 million barrels, implying that roughly one dollar invested would provide one barrel. Therefore, at US$27 per barrel, each additional dollar of investment would provide net

19/ IBRD Report No. 5094-EC "Ecuador: An Agenda for Recovery and Sustained Growth," October 1984.

revenues of US$11. 20/ This is by far the investment with the highest expected rate of return in Ecuador, the quickest pay-off, and the most dramatic impact on exports.

3.42 It is crucial to increase output in certain CEPE oil fields in the Oriente by means of artificial lift equipment, where about US$40 million in capital expenditures already have been made in developing the fields involved. At this time, the 34 wells that have been drilled are not producing, mainly because the reservoir pressure is below that necessary for natural flow. A forecast should be made by CEPE to estimate the dates when other wells will require artificial lift installations so the necessary actions can be taken to have such equipment available for each well when needed to avoid the major constraints resulting from procurement bottlenecks.

3.43 With respect to the rehabilitation of the Santa Elena oil fields, the World Bank is financing a study which would define a long-term rehabilitation program for the Santa Elena fields. The study will review available information on all existing wells (about 2,800) and identify wells for rehabilitation and new wells to be drilled; evaluate the feasibility of secondary recovery; and optimize well-spacing and drilling costs. In addition, studies presently carried out by CEPE are expected to define to what extent renovation is justifiable, and any other investments that can be made to make these fields economically productive again. The Government agrees with the mission that the Santa Elena Rehabilitation Project should be carried out under a joint-venture operation with an international private oil company because of the higher risk of the area and the low priority given by CEPE to developing fields in this area.

3.44 Included in development investments are provisions for drilling twelve development wells by CEPE and participation by CEPE in drilling nine development wells by the consortium. Were CEPE to continue investing in oil field development at the 1985 planned pace, its investment over the period to 1990 would be about 70 percent of the investment estimated by the World Bank to be necessary to achieve the production of 779 MMbbl. Preliminary estimates indicate that such a high case production could be achieved if investment in oil field development is stepped up to about US$120 million per year from the present US$83 million.

Refineries

3.45 Until recently, there was strong political pressure to start building a new 75,000 bd refinery -- Atahualpa -- at Guayaquil. The mission agrees with the GOE's present informal position to postpone this project indefinitely because of its very high investment cost (US$1

20/ The GOE receives US$13 per barrel (roughly 50% of price) and the additional cost of producing a barrel of oil in Ecuador is US$2.

billion) and negative rate of return. With the present refinery structure in Ecuador, there is no need for such an investment.

3.46 The expansion of the Esmeraldas refinery is justifiable although upstream investments may provide a far greater return to Ecuador. The Esmeraldas expansion project which has been under development for about six years is reaching the final stages of the bidding process. The expansion, which will cost an estimated US$125 million, will continue the existing refinery configuration 21/ and will also be accompanied by energy conservation measures. Although it is an integrated refinery including both catalytic and thermal cracking of feedstocks derived from the vacuum distillation unit, it notably lacks polymerization and alkylation units to maximize gasoline yield. This, however, allows a relatively high yield of LPG to help satisfy the most rapidly growing demand. The mission has estimated an internal rate of return of about 15% over a 15-year life, based on the current value of Oriente crude average 1984 product replacement costs, and a 10% capital cost overrun. 22/

3.47 With a potentially rapid growth of demand in the Oriente associated with both expanded exploration and production and related population growth, CEPE has decided to install a new Amazonas topping refinery of 10,000 bd in the area. The Amazonas refinery project is expected to give a good return on investment, in the range of 35-47%. 23/ The good return is basically attributed to savings in pipeline transportation costs from Esmeraldas to Quito and in road transport costs from Quito to the Oriente area. The project will also more fully use the existing, underutilized pipeline from Shushufindi to Quito. In addition, due to the proximity of the existing Shushufindi gas treatment plant to the new Amazonas refinery, integration of these two will improve efficiency in each of these two plants. The Amazonas refinery will have a total investment cost of US$23 million and will require an operating cost

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21/ The yield structure is reasonably well suited to domestic demand and the planned expansion will bring it closer to the demand pattern.

22/ When using a least cost analysis, the Esmeraldas expansion remains attractive (US$256 million with refining versus US$258 million in importing) using prices of June 1985 and a discount rate of 12% with amortization of 10 years.

23/ Due to the recent sharp decline in international fuel oil prices and the fact that the Amazonas refinery produces a large amount of fuel oil (42%), the mission recalculated the IRR using June 1985 prices. Although a much lower IRR of 14% was found, the mission still supports the commissioning of this refinery which is also attractive under the least cost analysis (US$68 million in refining versus US$69 million in importing) with a discount rate of 12% and amortization of 15 years.

(ex-fuel) of US$4.2 million per year. The justification for this refinery therefore is based both on satisfying local demand in the Oriente, and helping supply the Quito market, reducing the load on Esmeraldas and the Esmeraldas-Quito pipeline.

Transportation and Storage

3.48 The mission fully supports the expansion of the Transecuadorian crude pipeline and storage capacity. The Transecuadorian pipeline had a rated capacity of 240,000 bd with three pump units in each station until 1984 when a fourth pump was installed, increasing capacity to 280,000 bd. A fifth was recently installed, boosting capacity to 300,000 bd. The next expansions (additional pumping capacity) up to the ultimate live capacity of 400,000 bd will be scheduled depending on the size and timing of future discoveries which result from current exploration efforts by oil companies.

3.49 Petroleum products are transported by three existing major pipelines (Duran-Quito, Esmeraldas-Quito, Shushufindi-Quito), coastal tankers, and road tankers. CEPE is also planning three new product pipelines: Libertad-Pascuales, Libertad-Manta, and Pascuales-Cuenca-Machala (see Map IBRD No. 18930R). Libertad-Pascuales will link the refining areas in the Santa Elena Peninsula with Pascuales, the major terminal in the Guayaquil area, which represents the greatest market concentration. This link is important and should have priority consideration. The GOE should start constructing economic models on optimizing the integrated petroleum supply system for the medium to long-term period.

3.50 The pipelines Libertad-Manta and Pascuales-Cuenca-Machala do not appear to be economically justified. In the case of Libertad-Manta, marine transport in coastal tankers now being used is much less costly than pipeline transport (US$0.91/bbl 24/ compared to US$1.78/bbl). Similar arguments apply to the Pascuales-Cuenca-Machala pipeline, the economics of which are complicated by the leg inland to Cuenca. The transport costs of the proposed Libertad-Manta pipeline, compared with marine transport for the year 1988 (start-up of pipeline) are shown in Table 3.5.

24/ Using the international price of fuel oil at US$0.61/gal that applied during the assessment mission. Due to the sharp recent decline in international fuel oil prices (US$0.54/gal), the marine transport cost is reduced to US$0.84/bbl.

Table 3.5: LIBERTAD-MANTA TRANSPORT COSTS

Cost Category	Pipeline c/		Marine d/	
Amortization Interest Rate (%)	10.00	15.00	10.00	15.00
Amortization ($ million/year)	2.35	3.19	0.02	0.03
Operating costs	0.50	0.50	0.10	0.10
Total Pipeline/port line cost	2.85	3.69	0.12	0.13
Transport cost, a/ ($/bbl)	1.78	2.31	0.08	0.08
Shipping cost, b/ ($/bbl)	-	-	0.83	0.84
Total transport cost	1.78	2.31	0.91	0.92

a/ Throughput 1.6 million bbl.
b/ Based on current CEPE shipping contracts with Navipac and using opportunity cost of fuel oil at US$0.61/gal.
c/ Requires investment of US$ 20 million.
d/ Requires investment of US$ 210,000 for improvement on Manta port facilities.

Source: Mission estimate.

Recommendations

3.51 The following actions should be taken by the Government of Ecuador and CEPE to ensure an adequate petroleum supply:

Exploration

(a) Develop an exploration program for CEPE which should concentrate on those prospects located close to existing production infrastructure to reduce risks and permit rapid development of any new discovery for exploitation.

(b) Continue expanding to more areas the service contract forms which permit private capital companies to explore for and produce new discoveries of hydrocarbons. Private capital should be encouraged to explore in high risk regions such as the coast and offshore.

(c) Investigate the possibility of private participation in CEPE's producing blocks.

(d) Identify new areas for future petroleum exploration activities by carrying out an evaluation of possible sedimentary traps.

(e) Continue with the experimentation process for developing heavy crudes by encouraging private firms to drill in association with CEPE.

Petroleum Production

(a) Due to good discovery prospects, increase current production in areas such as Cononaco and, wherever feasible, through secondary recovery and use of artificial lift equipment. This would enhance production which would generate extra revenue for CEPE to use in financing exploration.

(b) Continue studies on defining to what extent renovation of the Santa Elena oil fields is justifiable to make them economically productive again.

Refineries and Transport

(a) Proceed with expansion of the Esmeraldas refinery and construction of the Amazonas refinery.

(b) Analyze how to optimize the integrated petroleum supply system by constructing economic models of the overall system including refineries, crude and product pipelines and terminals to use as an aid in investment planning.

(c) Carry out detailed studies on the need for and timing of the next expansions of the Transecuadorian crude pipeline.

Institutional Issues

(a) Redefine the future role of CEPE, especially in petroleum exploration taking into account the increased participation of private investors.

(b) Instead of duplicating CEPE's activities, DNH should concentrate on policy while CEPE should concentrate on operations.

(c) Analyze the petroleum legislation giving special emphasis to pricing and investigation of CEPE's autonomy so as to ensure CEPE functions in a timely and efficient manner. Immediate action should be taken to provide solutions to CEPE's procurement bottlenecks.

(d) Analyze CEPE's financial situation and distribution of oil revenues within the country's macroeconomic context.

IV. NATURAL GAS

Background

4.1 Known reserves of natural gas in Ecuador exist in the Gulf of Guayaquil and in the Oriente. The key issues in Ecuador's natural gas subsector concern market uncertainties for the Gulf of Guayaquil non-associated gas and more efficient use and recovery of the Oriente associated gas. The potential domestic market for gas in Ecuador is shown in Table 4.1 below.

Table 4.1: POTENTIAL DOMESTIC MARKET FOR GAS UTILIZATION IN ECUADOR (MMCFD)

	Non-Associated Gas in Guayaquil Area	Associated Gas in the Oriente
Power Generation	0 - 50	2.5 - 3.0
Industrial Use	10 - 40	4.0 - 8.1
Residential/Commercial Use	0 - 5	-
Chemical Feedstock	0 - 40	-
Transport	0 - 5	-
Recovery of condensable hydrocarbons a/	-	(7.8 - 18.2)
Total	-	6.5 - 11.1

a/ This is only the amount which is processed rather than consumed.

Source: Mission estimates.

4.2 Gulf of Guayaquil. The main constraints that need to be resolved before exploitation of the Gulf of Guayaquil gas can begin are: the unreliability of gas reserve estimates, the complex geology and the legal uncertainties relative to the Amistad structure. Initial exploration of the reserves was made by ADA Petroleum, which, in 1973, was forced to leave by the Government. ADA claimed rights in international courts and Ecuador believes it has a right to the reserves. In addition, dense faulting systems are present which makes it difficult to accurately determine the extent of the existing reserves.

4.3 To date, no hydrocarbon bearing structures besides the Amistad have been identified in the Gulf, and no production has been realized from the gas discovery. Proven reserves in the Amistad structure considered to be reliable range between 200 and 280 BCF with 80-90 BCF as probable (see Annex 9), and minor quantities of associated natural gas produced on the Santa Elena Peninsula. Reserves in the Amistad structure are expected to support a flow of some 50 MMCFD for at least 15 years.

4.4 The emphasis of exploration in the Gulf of Guayaquil has been in the search for oil. A total of 11 potential hydrocarbon-bearing structures have been identified and tested with exploratory wells. Past experience has placed future exploration in the high-risk category.

4.5 CEPE has called for bids, under exploration contracts, for four exploration blocks within the Gulf of Guayaquil (See IBRD Map No. 18930R), with a minimum requirement of 1,500 km of seismic survey, and 4 exploratory wells, within each block over a four-year period. Since the blocks were offered in late 1984, BELCO has signed contracts on Blocks 1 and 2, located adjacent to the Santa Elena Peninsula. Discussions with CEPE have revealed that no bids were received on Blocks 3 and 4.

4.6 The Amistad structure which contains the only proven reserves, has been set aside for CEPE. A proposal from Braspetro/Petrofertil is currently being considered for a three-phase program of exploration, production, and fertilizer plant development utilizing the Amistad natural gas reserves.

4.7 Oriente. The only associated gas reserves of any significance are in the oil-producing fields in the Oriente. The Oriente region contains recoverable reserves of approximately 195 BCF of associated natural gas, which is being produced at a rate of approximately 45 MMCFD scattered throughout the region as a by-product of the crude oil production. Probable output therefore depends on the oil output strategy. In addition to the increased recovery of condensable hydrocarbons from wet gas in the Oriente, the main issues to be considered are substitution of dry gas for other fuels in thermal and power applications and dry gas as a prospective transport fuel (CNG). An improvement in the use of dry gas in the Oriente is expected soon with the proposed new Amazonas refinery depending on this source as a fuel. Optimization of the liquids recovery facilities might well enable Ecuador to become self-sufficient in LPG in the foreseeable future while CNG utilization has the potential to reduce gasoline imports.

Gas Development in the Gulf of Guayaquil

4.8 The Gulf of Guayaquil is considered to be a gas short area, indicating the potential gas availability (50 MMCFD) is projected not to exceed the potential demand for it. Selection of the optimal configuration of gas utilization projects therefore constitutes the main issue. Based on current estimates of reserves and sustainable flow rates, a total fuel substitution of 50 MMCFD of non-associated gas equivalent could be realized.

Table 4.2: SUMMARY OF ECONOMIC ANALYSIS OF GAS UTILIZATION PROJECTS IN GUAYAQUIL
(10%-20% discount rate per year)

Project/Package	Investment a/ [Flow rate]	Gas Netback	NPV b/
	10^6 US$ [MMCFD]	US$/MMBTU (negative)	10^6 US$ (negative)
I. Power Generation	9.6 - 19.2 [50]	6.11 - 6.43	100.7 - 299.8
II. Industrial fuel	8 [40]	4.92 - 5.04	32.2 - 94.2
Residential/ Commercial fuel	2.5 [5]	7.04 - 7.15	24.7 - 41.8
Transport fuel	3.5 [5]	6.30 - 6.48	18 - 31.5
Package total	14	5.29 - 5.40	74.9 - 167.5
III. Ammonia/Urea	320 [40]	(0.14) - 0.83	(203.0) - (193.7)
Industrial fuel	2 [10]	6.11 - 6.39	21.0 - 37.6
Package total	322	1.11 - 1.94	(182.0) - (156.1)
IV. Methanol	102 [40]	(2.43) - (1.53)	(431.2) - (317.0)
Industrial fuel	2 [10]	6.11 - 6.39	21.0 - 37.6
Package total	104	(0.72) - 0.05	(410.2) - (279.4)

a/ Excluding exploration development and transport costs.
b/ Based on fuel oil equivalent value of natural gas at US$4.19/MMBTU.
Source: Mission estimates.

4.9 Power generation is the most attractive choice for utilization of the Gulf of Guayaquil gas. However, the expansion of INECEL's transmission and distribution system within the next five years will reduce the need for gas in power generation. Industry also is a potentially large volume user of gas in Ecuador, but the netback value of gas in general would be lower because of the fuel oil displaced. Attractive low-volume, high value markets are the residential/commercial and transport sectors. The utilization of gas as chemical feedstock for fertilizers is not attractive in the foreseeable future because of the small size of the local market as well as depressed international market conditions. All of the above are mainly constrained by legal arguments dealing with the exploitation rights of the Amistad structure explained before, and the high investment cost required (shown in Annex 10). Table 4.2 summarizes the results of the preliminary economic analysis of gas utilization in Guayaquil. A prefeasibility study on the market potential of gas should be carried out dealing in detail with the factors mentioned below.

Economic Analysis

4.10 Economic Price of Gas. As a prospective gas-short area, the economic price of gas from the Gulf of Guayaquil would follow that of fuel oil on an energy equivalent basis. The first step is the calculation of gas netback values which are compared with the price of gas. The economic price of gas in this case is US$4.19/MMBTU, which is the opportunity cost of the cheapest fuel replaced (fuel oil).

4.11 For the purpose of the economic analysis, the following project packages have been considered for utilization in: (a) power generation; (b) industrial, residential and transport purposes; (c) chemical feedstock for a fertilizer plant and industrial use; and (d) chemical feedstock for a methanol plant and industrial use. Table 4.3 presents specific details about the four packages.

Table 4.3: PROJECT PACKAGES - GULF OF GUAYAQUIL GAS

	End Use	Demand (MMCFD)
I.	Power Generation	50
II.	Industrial	40
	Residential	5
	Transport	5
III.	Fertilizer Plant	40
	and Industrial Use	10
IV.	Methanol Plant (1,000 TPD)	40
	and Industrial Use	10

Source: Mission estimates.

4.12 Infrastructure requirements. Development of the Amistad natural gas requires additional investments in exploratory and production drilling, gas production platforms and transport infrastructure. The total capital cost for infrastructure has been estimated at US$230.7 million for the project packages I, II, and IV. The package III -- which is related to the Atahualpa fertilizer complex, 25/ -- needs an estimated investment for infrastructure of US$227.8 million.

4.13 Power Generation. Although utilization of natural gas for power generation is the most economically attractive option, its implementation highly depends on INECEL's generation policy since the expansion of INECEL's transmission system in the next five years will reduce the need for gas in the power sector. Project package I refers to the production and transport of gas from the Amistad structure to the area near the city of Guayaquil where EMELEC and INECEL thermal plants are located. The gas would replace diesel oil as fuel for electricity generation where a total effective capacity of 192 MW would be involved. Netback values on replacing diesel oil with gas in power generation, as shown in Annex 10, vary from US$6.11 to US$6.43 per million BTU according to project lifetime (5 to 15 years), discount rate (10 to 20%/yr) and retrofit investment (US$9.6 or 19.2 million). NPV's vary for the same set of parameters, from US$100.72 million to US$299.77 million.

4.14 If package I could be implemented right when Guayaquil gas becomes available, it would provide the necessary time for the industrial fuel market to develop. Later on, the combined demand in the industrial, residential/commercial and transport sectors could take over gas demand entirely from the power sector as the latter switches to hydroelectricity. In that case, timing would be the essential criterion.

4.15 Project package II, which is economically sound, refers to the production and transport of gas from the Amistad structure to the area near the city of Guayaquil where it would be consumed in industry (40 MMCFD), in the residential/commercial sector (5 MMCFD), and in transport (5 MMCFD). However, besides the constraints mentioned in para. 4.9, there is also a difficulty in coordinating the industrial market.

4.16 For industrial use, gas netback values vary between U$4.92-5.04/MMBTU and NPV's vary from US$32.2 million to US$94.2 million, depending upon discount rates and project duration, and according to the consumption of 40 MMCFD of gas as an industrial fuel. The fuels displaced are a combination of fuel oil, diesel oil and kerosene, the opportunity cost of which is estimated at US$5.11/MMBTU. Annex 10 shows the breakdown of gas netback and NPV of gas as an industrial fuel for various discount rates and project lifetimes.

4.17 For residential/commercial use, the gas netback values range from US$7.04 - 7.15/MMBTU and NPV's vary from US$24.7 million to US$41.8 million, depending on the discount rates used and based on the consumption of 5 MMCFD of gas as fuel. The fuel displaced is LPG, the opportunity cost of which is estimated at U$7.33/MMBTU. The demand in itself would not justify the development of gas infrastructure in Guayaquil, but

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25/ It recently has been reported that the Government is reconsidering the fertilizer complex as was recommended during the assessment mission.

once the pipeline is built to meet power/industrial demand, the household/commercial market, although small, can become very attractive.

4.18 For transport, gas netback values range from US$6.30-6.48/MMBTU and NPV's vary from US$18 million to US$31.5 million, depending upon the discount rates adopted, and assuming 5 MMCFD of gas is consumed in the form of CNG as transport fuel. The fuel displaced is gasoline which has an opportunity cost of US$6.71/MMBTU.

4.19 Fertilizer Plant and Industrial Use. Package III, which refers to the production and transport of gas from the Amistad Structure in the Gulf of Guayaquil to Atahualpa where the gas would feed a fertilizer plant with capacities of 1,000 TPD of ammonia and 1,650 TPD of urea, is not an economically attractive option for gas utilization. 26/ While the size of the plant is considered economic by international standards, in view of the small size of the nitrogen fertilizer market in Ecuador, the bulk of its production should be placed in the depressed international fertilizer market which is expected to continue for quite some time into the future. By 1990 the export requirements would be on the order of 900 TPD or 60% of total urea production. Annex 11 explains the assumptions underlying the economic analysis of the ammonia/urea option for gas utilization.

4.20 Methanol Plant and Industrial Use. Package IV, which has not turned out to be economically attractive, refers to the production and transport of gas from the Amistad structure to the area near the city of Guayaquil, where it would be consumed in a prospective 1,000 TPD methanol plant (40 MMCFD) and as industrial fuel (10 MMCFD). Methanol would be consumed in the local, domestic market as a gasoline component serving the dual function of gasoline extender and octane booster. Since the price of methanol is historically correlated with gasoline, methanol is valued at 60% of the economic value of gasoline, namely US$4.82/MMBTU. It is unlikely that under current and foreseeable conditions this project ever will be implemented.

Oriente - Efficient Use and Recovery of Gas

4.21 Historically, natural gas produced in the Oriente has been flared (62% in 1984), with only nominal volumes utilized as fuel gas and for gas lift operations associated with the crude oil production. While flaring of gas is wasteful, two factors should be noted: (a) the production areas are extremely remote from populated and/or industrialized areas and completely lacking in any utilization infrastructure, other than those of the crude oil production facilities; and (b) the gas/oil

26/ World commodity prices projected by the World Bank Economic Analysis and Projection Department (EPD).

ratios for the production are low, resulting in relatively small volumes of natural gas produced.

4.22 Although from the economic point of view recovery of gas in the Oriente is attractive, additional constraints such as non-concentrated market, and lack of coordination between CEPE and the consortium impede its implementation in the short term. Due to the reduced economic activity in the area other than for petroleum production, the Oriente could be categorized as a gas-surplus area relative to foreseeable local demand. 27/ The mission has provided a preliminary economic analysis, as shown in Table 4.4 below.

Table 4.4: SUMMARY OF ECONOMIC ANALYSIS OF GAS UTILIZATION PROJECTS IN THE ORIENTE
(10% to 20% discount rate per year)

Project/Package	Investment	Gas Netback	NPV
	(10^6 US$)	(US$/MMBTU)	(10^6 US$)
1. Petroleum Operations			
- Diesel Oil Substitution	0.33	5.77 - 6.35	0.51 - 8.1
- Centrifuged Crude Oil Substitution	0.25	4.04 - 4.30	1.1 - 2.0
2. Libertador Recovery of Condensates			
- pipeline	7.7	1.58 - 1.85	3.31 - 6.98
- road transport	4.0	2.20 - 2.31	7.06 - 10.73
3. Power generation	2 - 4	5.97 - 6.34	37.14 - 64.93

Basis: Oriente: gas-surplus area; economic price of gas equal to US$1.00/MMBTU.

Source: Mission estimates.

4.23 Economic Price of Gas. Since the demand/supply balance is such that the point of economic depletion is far into the future, the economic price for gas becomes the long-run marginal cost of gas production and delivery. This is likely to be very small as gas is co-produced with petroleum. The mission has estimated that if 10% of the cost of crude production (US$2.00 bbl) is allocated to gas, this would be equivalent to US$1.00/MMBTU, which becomes the economic price of gas.

4.24 Petroleum Operations. Oil and gas handling in the Oriente requires mechanical energy for pumps, compressors and turbines. Liquid

27/ With a maximum flow rate of associated gas of 45 MMCFD, the range of potential demand is only 6.5-11 MMCFD.

fuels such as diesel fuel and centrifuged crude oil are convenient fuels for such applications. Although the amounts consumed are small, the utilization of gas in petroleum operations could provide a high economic return on the modest investments required to convert existing machinery to burn gas. Consequently, the mission recommends the implementation of this substitution.

4.25 For diesel oil substitution, in the oil fields of Sacha and Lago Agrio, the range of gas netback values is US$5.77-US$6.35/MMBTU. For centrifuged crude oil substitution, in the Auca oil field, the gas netback range is lower at US$4.04-4.30/MMBTU, but still well above the economic price of gas in the Oriente. Annex 12 includes the economics of industrial utilization of gas in petroleum operations in the Oriente.

4.26 Recovery of Condensates. Since 1984, the Shushufindi treatment plant has been functioning well below its design capacity of 25 MMCFD. It has been reported that the volumes processed by the natural gas plant rose to a maximum of approximately 10 MMCFD by the end of 1984, as a result of a lack of feedstock. The two short term solutions which are feasible and capable of increasing the gas supply to the treatment plant are: better coordination with the consortium, and bringing in the gas from CEPE's Libertador oil field.

4.27 The consortium retains significant volumes of wet gas for gas lift purposes instead of transporting it to the treatment plant and returning dry gas for its operations. It does this because the priority of the consortium is in oil production and it does not want the natural gas production to interfere with its emphasis. Thus, the consortium provides to the gas plant only its surplus. The mission does not consider that the use of dry gas from the plant will interfere with the consortium's operation and recommends improving the coordination with CEPE in order to optimize the utilization of natural gas. 28/

4.28 The proposed Libertador project is only marginally attractive from the economic viewpoint due to: the reduced volume of liquids produced; the valuation of natural gasoline as crude oil, since it is blended wih the latter; the flaring of the residual gas; the relatively high investment costs, particularly at Libertador; and the decrease in gas flow rate from 7 MMCFD by a factor of 3 in only 10 years. 29/ Gas netback values are slightly higher when considering road transport of condensates from Libertador to the Shushunfindi treatment plant because of the reduction in investment cost from US$7.7 million with pipeline to US$4 million with road. Gas netback values range from US$2.20-2.31/MMBTU with road transport of condensates to US$1.58-1.85/MMBTU with pipeline.

28/ The GOE has already taken measures to improve the coordination.

29/ Since the assessment mission, the GOE no longer considers the Libertador gas project.

NPVs range from US$7.06-10.73 million (road transport) to US$3.31-6.98 million (pipeline). The economics would improve drastically if the residual gas in Libertador could find an economic use as a fuel such as CNG for transport. However, even this use is limited by the lack of roads and low demand. On the positive side, the recovery facilities (Shushufindi gas plant) and transportation network (the condensates pipeline to Quito) are in place to ensure that the LPG and natural gasoline reach suitable marketing centers. Annex 12 provides a breakdown of the Libertador project investment cost including pipeline.

4.29 Power Generation. The power potential required by petroleum operations is around 40-45 MW, most of which depends on diesel fuel. Gas has already penetrated this market, particularly at Shushufindi, but could expand its share of the power generation market if processed prior to burning to obtain a steady and adequate composition.

4.30 The sparsely populated Oriente depends on diesel generators to supply electricity to the residential, commercial and public sectors. Given the high cost of diesel fuel delivered to the villages, the latter are supplied with electricity for only 10 hours daily. The amount of gas required to substitute diesel fuel would be quite small given the limited demand, but costly diesel would be saved for just a small investment in adapting the diesel generators to gas use.

4.31 From the economic point of view, utilization of natural gas in power generation is an excellent alternative. However, due to the large area covering the potential demand, implementation of a full scale gas replacement program is not feasible in the short term. Gas netback values vary within the range of US$5.97-6.34/MMBTU -- depending on the discount rate used (10-20%) -- which is much higher than the economic price of gas. The net present values of the retrofit program vary in the range of US$37.14-64.93 million. This was calculated by considering the energy replacement value of gas when substituting diesel oil at US$6.51/MMBTU and a power production cost equal to 1.25 times the economic price of gas. Annex 12 provides a breakdown of the gas netbacks and NPVs from substituting gas for diesel oil.

Recommendations

4.32 Specific recommendations for gas development in Ecuador are the following:

Gulf of Guayaquil

(a) Remove legal uncertainties resulting from past exploration of the Amistad structure.

(b) Establish reliable gas reserve estimates, by resorting to joint ventures in exploratory drilling.

(c) While carrying out renewed exploration work, undertake a comprehensive gas market study which should consider a selection of project packages focussing on power generation, industrial fuel, and in the residential/commercial, and transport markets.

Oriente

(a) Improve coordination between CEPE and the consortium to process wet gas from the consortium at the Shushufindi plant.

(b) Initiate long-range planning studies to ensure adequate feedstocks are available to the Shushufindi gas plant and investigate the feasibility of establishing satellite gas plants in new fields at remote locations; including evaluation of transport methods to ship the liquids to suitable collection/processing installations.

(c) Substitute dry residual gas for other petroleum fuels used in power generation and thermal applications, expanding on what is already being done by the Shushufindi gas plant.

(d) Use dry residual gas for gas lift operations as supplies of dry gas increase and become more dependable. Use of wet gas should be allowed only where dry gas supplies are interrupted for shutdowns or breakdowns, to avoid curtailing crude oil production activities.

V. ELECTRICITY

Background

5.1 The principal issues confronting the electric power sector in Ecuador are: (a) the adequacy of present generation and transmission expansion plans in the light of reduced demand growth and the availability of alternative energy sources (gas, geothermal); (b) short-term generation expansion problems stemming from unforeseen technical difficulties in the Paute River basin; (c) institutional problems related to INECEL's organization and financial difficulties, and determining the future of EMELEC -- the private company that serves the major load center of Guayaquil; (d) operational problems associated with minimization of generation cost, reliability and quality of service, and distribution losses.

5.2 The electric power sector in Ecuador is organized around the Instituto Ecuatoriano de Electrificacion (INECEL) which operates as a planning agency as well as a generation and transmission company. It sells energy to 18 distribution companies over which it exerts nominal control through ownership of the majority of their shares. However, the largest market in the country (Guayaquil) is supplied by a private foreign company (EMELEC) which has operated since 1926 under a concession that expires in October, 1985. In addition, a number of municipal companies distribute electricity locally by purchasing power from INECEL subsidiaries.

5.3 The electric power sector has gone through three distinct phases over the past three decades. In the 1960s, 30/ electric utilities operated either independently or with minimal interconnections, and INECEL which had very limited resources, acted as a government regulatory agency. In the 1970s, Ecuador's oil boom endowed INECEL, with abundant resources proceeding from petroleum royalties, resulting in INECEL consolidating its control over subsidiaries and becoming a generation and transmission enterprise. During this period, a phenomenal growth in electric power consumption occurred; per capita consumption increased from 110 kWh in 1970 to 311 kWh in 1980 (11% average growth rate). In the 1980s, there has been a complete reversal from thermal to hydro generation, mostly as a result of the commissioning of Paute A and B hydro plants, and INECEL has become the main power supplier. However, the 1982-1983 recession and reduced oil export revenues combined to reduce demand and available financial resources.

30/ INECEL was created in 1961.

Basic Resources and Existing Facilities

Generation

5.4 Ecuador has three main economic sources of primary energy for power purposes: hydro, natural gas, and geothermal. Hydropower, Ecuador's most important commercial energy resource, is estimated at about 93,000 MW, of which 30,000 MW have been identified in 11 watersheds. The identified economical potential to date is 21,000 MW, distributed among 39 projects. Unit costs for these projects fluctuate between 18 and 63 mills/kwh (1983 price levels). Natural gas (non-associated), from the Gulf of Guayaquil is another alternative for power generation (see para. 4.28-4.29); proven reserves are estimated between 200 and 280 billion cubic feet (BCF). Surface manifestations of geothermal energy sources can be found in many different places in the Andes mountains. However, none of these have been investigated thoroughly, and only the Tulcan-Chiles region in the Carchi province is being prospected in detail with assistance provided by the Italian Government. Geothermal reserves are roughly estimated by INE to be as high as 60,000 MW.

5.5 Ecuador at present has a total installed capacity of 1628 MW (45% hydro) for serving a load of 810 MW. Once Agoyan (156 MW) is finished, there will be enough generating capacity to satisfy demand until 1993. Although there are 903 MW in thermal units, most of the load is served by hydro units and the apparent excess capacity is due to the commissioning of hydro facilities for the purpose of substituting oil-based fuels. Of the total hydro capacity, the Paute A-B complex accounts for 69% and supplies most of the system's load. Thermal substitution has been highly successful with hydro accounting for 76% of total generation in 1984. Of the latter, 80% corresponded to INECEL plants.

Transmission and Distribution

5.6 The backbone of the transmission system consists of the 230-kV Paute-Guayaquil-Quito double circuit lines (510 km). Major loads are served through 138 kV extensions (590 km) that also interconnect other hydro plants (e.g. Pisayambo). The 230 kV transmission system is also the main structural weakness regarding supply reliability -- outages of the Paute-Guayaquil lines produced three total blackouts in 1984. Transmission reinforcements, due to be in service by 1988, consist of a Paute-Ambato-Quito line that will create a 230 kV ring, thus improving reliability. A number of 69-kV radial lines complement the grid to provide service to the transformer stations which feed the distribution network. Total connections are 951,000. Table 5.1 provides the basic characteristics of the Ecuadorian power system. IBRD Map No. 19042 shows the country's power system.

Table 5.1: BASIC CHARACTERISTICS OF THE ECUADORIAN POWER SYSTEM - 1984

Installed Capacity	
Hydro	725 MW
Thermal	903 MW
Total	1628 MW
Peak Demand	810 MW
Annual Gross Generation (1984)	
Hydro	3207 GWh
Steam Oil fired	721 GWh
Gas Turbines	16 GWh
Diesels	273 GWh
Total	4217 GWh
Final Demand (1984)	3288 GWh
Aggregated losses a/	22%
Transmission Lines	
230 kV	510 km
138 kV	590 km
Substation Transformer capacity	2678 MVA

a/ Includes: transmission (5%) and subtransmission and distribution losses (17%).

Source: INECEL.

Electricity Growth and Demand Forecasts

5.7 Despite high growth rates in the 1970s, Ecuador's per capita consumption of around 497 kWh is still low compared to other countries in the area (Colombia 800 kWh, Chile 730 kWh). The electrification rate 31/ increased from 28% in 1970 to 61% in 1984 with very substantial differences between urban and semiurban/rural areas.

5.8 Due to highly favorable economic conditions, electricity demand in Ecuador has grown at exceptionally high rates in the recent past: 12% per year for 1970-75 and 17% for 1975-80. The underlying causes for these exceptional rates were increased wealth (the oil boom), industrialization, and important investments in electrification that incorporated new customers into the system. For the future this combination of factors will probably not repeat itself, since as of 1983, growth in

31/ The number of inhabitants with access to electricity relative to the country's population.

consumption had decelerated to 7% per year and preliminary data for 1984 indicate a demand growth rate of only 2%.

5.9 INECEL's demand forecasts, which are based upon an econometric model relating consumption to GDP and sales, show the short-term growth rates at 6.2% for 1985-1990, 6.9% for the medium term (1990-1995) with improvements in the economy, and 8.5% for the long-term (1995-2005). 32/ The overall estimates seem reasonable for planning purposes given past experience and the inherent uncertainty that surrounds such forecasts. Under these conditions, the demand of public utilities is expected to grow from the current 808 MW to 1600 MW in 1995, and 3600 MW in 2005. Annex 13 shows INECEL's demand projections.

Short Term Expansion Plans

5.10 Generation. The 1985-1995 decade will witness four hydro projects: Agoyan, Daule Peripa, Paute C and Paute Mazar. Agoyan (156 MW) is under construction and should come on line by 1987; Daule Peripa (130 MW), which is a multi-purpose project, has completed designs and work is expected to start in 1987; Paute C (500 MW) is underway and civil works have been already contracted; and Paute Mazar (174 MW) is still under study.

5.11 Problems with the Mazar project are related to the Paute development. The Paute-Amaluza dam is silting at about 3.5 million m^3 per year; the dead storage volume of the existing Paute-Amaluza reservoir is about 36 million m^3 and would silt in about 10 years, after which time turbine operation might become difficult. Paute C is the third phase of a hydropower complex constructed in the Paute River. This complex consists of an existing 160-meter dam and a 500-MW hydropower station that is already in operation. The Paute C project would consist of an additional tunnel and another hydropower plant, using the existing Paute-Amaluza reservoir to feed the new plant. Because the project makes better use of an existing dam, it appears very attractive, as it would cost only about US$250 million and would have an installed capacity of 500 MW, for a cost of US$500/kW.

5.12 Possible solutions to the silting problem, identified by INECEL in January 1985, include: (a) constructing the upstream Paute Mazar dam and reservoir; (b) installing a conventional dredging system 33/ (c) developing a new intake structure that would operate at variable levels according to the rise in the sediment level; and (d) constructing a sediment trap and a diversion tunnel that would take the sediments from

32/ Since INECEL recently indicated that the long-term forecast could be too high, a periodic review should be carried out.

33/ This would not be a definitive solution but would help to reduce the silting rate.

upstream of the reservoir and carry them to a place located downstream of the Paute Amaluza dam. IBRD map No. 19295 illustrates the alternatives to the Paute silting problem. 34/

5.13 Paute Mazar consists of a large multi-annual reservoir upstream from the existing Paute plant. Associated to the reservoir is a relatively small hydro plant (174 MW). The benefits from the Mazar project can be summarized as follows: (a) regulation of the Paute River, therefore benefitting the Paute A, B, C and other future downstream projects such as Sopladora (500 MW) and Cardenillo (840 MW); (b) sedimentation control, thus preventing the silting of the existing Paute reservoir. The benefits and estimated costs of Paute Mazar are shown in Table 5.2:

Table 5.2: PAUTE MAZAR BENEFITS AND ESTIMATED COSTS

BENEFITS (Firm Gwh/year)	
Paute Mazar	520
Paute A, B, C	+782
Sopladora	+443
Cardenillo	+595
TOTAL	2340
COSTS (M$ of Jan '84)	
Interest Rate	8%
Direct Cost	617
IDC	204
TOTAL	821
Annual Cost	69
GENERATING COSTS	
US¢/kWh a/	2.9
US¢/kWh b/	5.3

a/ If Sopladora and Cardenillo are undertaken.
b/ If Sopladora and Cardenillo are not undertaken.

5.14 If the Mazar plant is to be judged simply on energy terms, it can only be concluded that a decision to proceed with its development is contingent on further information with respect to the feasibility of downstream plants. The unit costs calculated above are reasonable when compared to other projects in the expansion plan (e.g. Chespi-US¢2.8/kWh, Chambo - US¢2.9/kWh - at 8% discount). However, the conclusion that Mazar could be justified on this basis is based upon the assumption that the Sopladora and Cardenillo plants are undertaken. If, due to results of feasibility studies and/or designs, these developments prove to be

34/ Since the assessment mission, INECEL considers alternative (b) to be the optimum solution and alternative (d) to be too costly.

uneconomical, the corresponding costs of Mazar increase to US¢5.3/kWh, a value that is excessive if compared to other developments.

5.15 Apart from its energy implications, Paute Mazar must be considered as a long-term solution to the sedimentation of the existing Paute reservoir. If no measures are taken, Paute A, B and C would have to operate as purely run-of-the-river plants with no regulation. As a result there would be a loss of 140 MW in Paute A, B, C due to the lower head, in addition to higher operating costs.

5.16 Given the complexities of the problem, and taking into account that other technical alternatives (such as a dredging system, a new intake and a sediment trap) should be analyzed in detail, the mission recommends the following course of action: (a) complete the list of possible technical alternatives to solve the silting problem; (b) evaluate the least-cost solution under two possible scenarios: (i) assuming that Sopladora and Cardenillo projects are undertaken, and (ii) assuming that these projects are postponed; (c) accelerate as much as possible the feasibility studies for Sopladora and Cardenillo in order to make a decision with respect to Mazar in 1986-87.

5.17 At this point it is important to analyze, expost, whether the Mazar problem points out a planning deficiency in INECEL, or whether the difficulties can be attributed to chance. In this respect, the Paute complex and Mazar were designed and conceived as an integral development. The original site for Mazar proved inadequate due to geological difficulties after Paute A and B were commissioned. As a result, the dam has been relocated upstream with negative consequences; i.e., its size and cost have increased, its regulating capacity is smaller and it does not receive the influx from the Mazar River that originally flowed into the reservoir. Given these events it can be said that the Mazar problem is more a result of insufficient information rather than poor planning. However, the problem does point out the need to count on feasibility studies for the crucial projects of a given river basin before starting major developments on it.

5.18 Transmission. Definite transmission expansion plans exist for 1985-1991. They consist of (a) transmission reinforcements in order to complete the 230-kV ring encompassing Quito and Guayaquil, (b) transmission lines that connect generating plants to the main ring, and (c) 138-kV radial in order to incorporate new regions to the system. All these plans contribute to (a) deliver all Paute A-B energy to the system, (b) increase reliability (considering that most of the supply should originate in Paute), and (c) open up markets for hydro energy that will substitute present bunker or diesel plants. These benefits should make the reinforcement of the transmission system (including substations) one of the highest priority items on the investment agenda.

5.19 Subtransmission and Distribution. The total budget for subtransmission and distribution is around US$137 million for 1985-1988. Additionally, US$66 million are budgeted for rural electrification. In physical terms, projected investments call for 808 MVA in new substations or expansions thereof. Of these additions, 412 MVA correspond to areas outside Quito or Guayaquil.

Long Term Expansion Plans

5.20 INECEL's methodology for long-term planning consists of a well-structured set of models that enable them to formulate least cost plans for a given demand forecast. These models could be strengthened with additional programs that would take into account the stochastic nature of hydro energy in greater detail than the present ones. As is customary in these studies, generation plans are formulated first, with a relatively large horizon (20 years), and tranmission plans are adjusted according to the resulting location of generating facilities. In this respect, INECEL plans to continue development of 230 kV lines; higher voltages are not necessary given the size of the system. INECEL has a capable planning staff for developing models; however, they could be strengthened through technical assistance and, in particular, with the advice of those consultants who helped in developing the existing models.

5.21 The long term plans (1996-2010) call for a predominantly hydro development. Most of the projects have studies at the prefeasibility or assessment stage. Given that all the projects are in the Andes mountain range, problems (geological ones in particular) are to be expected. Thus, one of the main efforts to be made in the short-term is to advance these projects to the feasibility stage in order to take advance measures if some of them do not prove economical. Between 1985-1990, INECEL plans to invest around US$100 million for studies of all the projects included in the long-term plan. This should provide ample lead time to change the long-term plan if major difficulties are found.

5.22 Long-term plans should take into account other resources such as geothermal or natural gas. Concerning geothermal, INECEL should closely monitor the pilot project being developed with ICEL, the Colombian utility, in order to confirm whether the resource is competitive with hydro plants. With respect to gas, once reserves in the Gulf are assessed, INECEL should coordinate with CEPE a pipeline feasibility study in order to determine whether the resource can be economically used for thermal generation. In order for CEPE to be able to assess the investment in additional exploration, INECEL should conduct a study to provide CEPE with the electrical sector's demand for natural gas at different delivery prices.

System Operations

5.23 INECEL at present is the major source of generation for the country and it is conscious of the need to minimize thermal costs. Perverse incentives induced by low retail prices for petroleum products create contradictions between the need to replace fuels (fuel oil and diesel oil) and the need to reflect long-run marginal costs -- fuel-oil based generation costs around US¢1.5/kWh compared to a long-run cost of US¢2.6/kWh. INECEL therefore has implemented agreements that induce its subsidiaries to purchase energy instead of generating it. However, this type of measure translates into low block sales tariffs that adversely affect INECEL's finances.

5.24 As seen by INECEL staff, the utility's major operating problem consists of the lack of flexibility in procurement: a clear example is the transformer lacking in a Guayaquil substation that would save US$1 million/month for a cost of US$0.75 million. Although operations staff have clamoured for action in this respect, red tape has held up delivery by a year or more. Procurement is further complicated by limitations on expenditures the company can authorize: by law, all expenses above about US$10,000 have to be approved by the Board of Directors. 35/ This creates congestion in decision-making that in practice involves the Board in the daily running of the company.

5.25 The quality of service has deteriorated since the Paute plant was commissioned: three major contrywide blackouts have occurred in the last two years. The causes have been associated with: (a) startup problems and (b) the reliance on a single double circuit, 230-kV line for Paute production. These problems should be solved once the Agoyan plant comes on line and the 230 kV ring is closed.

5.26 While subtransmission and distribution losses on a national scale average 17%, they are quite variable within the system. For example, the Santo Domingo system has losses on the order of 27%, whereas EMELEC has losses of about 9%. However, it is necessary to distinguish between technical losses and losses caused by invoicing errors and theft. The mission considers that this is a case in which an analysis must be made on a company-by-company basis; initially, concentration should be focused on invoicing and theft problems rather than on placing too much emphasis on technical losses, which could be reduced later. 36/

Sector Finances

5.27 The Ecuadorian power subsector has been facing serious financial problems for a number of years. These problems only became apparent at the turn of the decade, after the sector had started on an ambitious investment program designed to replace thermal with hydroelectric generation and to interconnect the country's isolated regional systems to a national power grid. At the time, the country was enjoying

35/ This limit has been extended to US$100,000.

36/ The analysis has recently been initiated.

unprecedented prosperity arising from the increase in oil prices and its incipient role as an oil exporting country. In this context it was decided that the costs of the investment program were to be funded by oil revenues and not by consumers through tariffs. The subsequent decline in oil prices and the concurrent Latin American debt crisis found the sector ill-prepared to face financial realities. Since other sectors are seen to have a higher priority, INECEL and its subsidiaries should seek to identify and use some of their own resources for financing the expansion program.

5.28 Past tariff policy resulted in negative operating incomes for 1983 and 1984, although some improvements occurred in 1984 because of reduced fuel expenses associated with the starting of the Paute hydroelectric plant. Net internal cash generation also has become increasingly negative over the period. In 1984, it was about -US$67 million and would have been more negative but for the rescheduling of a portion of the debt amortization that had become due.

5.29 The large diferences between present rates and marginal costs show up dramatically in the financial situation. If the sector is to become self-reliant by 1988 it should seek an average rate increase on the order of 85% by that date. However, INECEL's own projections indicate that they propose to continue relying on oil royalties by up to US$129 million for 1988. This divergence of views should be cleared up within the government by making a formal agreement with INECEL concerning tariffs and contributions which would establish a consistent policy.

5.30 The sector should define a financial strategy that will increase net internal cash generation, reduce its dependence on oil revenues and external borrowing. Government contributions through the National Electrification Fund should be maintained over the next years but on a level compatible with the country's priorities. The financial situation of the sector has to be assessed in relation to economic conditions by considering the following: (a) macroeconomic problems suggest that the sector should abandon its almost total reliance on the Government to fund its needs; (b) difficult access to foreign borrowing makes this financing source unrealistic, with the possible exception of some supplier's credits; and (c) fuel price subsidies will have to be reduced significantly in the next few years in accordance with the country's fiscal requirements.

5.31 Within the sector there is a lack of financial discipline that translates into excessive accounts receivable by INECEL. The current debt for energy sales from INECEL to its subsidiaries is equivalent to nine months billing, and INECEL shows correspondingly unfavorable liquidity ratios.

5.32 Despite its poor financial evolution, the debt structure of the sector is good, as government contributions have allowed it to limit the reliance on borrowings as a source of funding. The sector's debt/equity ratio of December 31, 1983, was around 34:66, and INECEL's ratio was 28:72 by the end of 1984, which is quite low by normal sector standards.

The Power Sector Investment Program

5.33 In order to meet energy demand, take advantage of economies of scale in generation, and reduce distribution losses during the coming years, INECEL and its subsidiaries have prepared generation, transmission and distribution construction programs for 1985-1988. The specific objectives of the power sector expansion plan are: (a) to finalize the construction the Agoyan hydroelectric project; (b) to initiate the construction of the third phase of the Paute generating complex (Paute C) and the Daule-Peripa hydropower component; (c) to add transmission and subtransmission lines; and (d) to conduct feasibility studies. INECEL's investment program would amount to about US$800 million (1984 prices) -- and would absorb about 20% of available public sector investment funds. Table 5.3 presents INECEL's investment program in the power sector for 1985-1988.

Evaluation of INECEL's Investment Program

5.34 Short term economic conditions are such that a reduction in public investment will be necessary in the 1985-88 period. Taking into account the Public Investment Review requested by the GOE and conducted by the World Bank in May of 1985, the mission reviewed the electrical sector's proposed investment program with the purpose of seeking an overall reduction of one third. In formulating an alternative investment plan, the mission has sought to postpone lower-priority projects. The following specific considerations were taken into account: Agoyan will enter into operation in 1988 and that new generating capacity will not be needed before 1993; Paute C should be deferred (one or two years) until more information on sediments and ways to handle them is available; and Daule-Peripa hydroelectric project is not needed until the early 1990s and could be delayed one or two years. 37/ The deferment of investments in new hydro projects could entail an economic cost due to the need for a more intense use of existing thermal facilities (bunker-fueled plants in particular); moreover, given the large reserve capacity of the system, supplies would not be jeopardized by this measure. Table 5.4 shows the investment program recommended by the mission.

5.35 The Agoyan project, started in 1982, is scheduled to be finished in 1987. This project is a priority for the generation expansion program. The civil works are substantially advanced and the equipment has already been ordered. To finish the project would require about US$80 million (1984 prices). The mission considers that the project should be finished according to INECEL's schedule.

37/ The GOE has already decided to implement Paute C and Daule-Peripa.

Table 5.3: INECEL'S INVESTMENT PROGRAM
1985-88

Investment Category	Installed Capacity (MW)	Total Cost (million US$ 1984)	Construction Period
Generation	960	345.7	
Agoyan	156	78.8 a/	1982-88
Paute "C"	500	183.3	1985-91
Daule-Peripa	130	60.5	1988-90
Paute mazar	174	23.1	1988-95
Transmission & Substations	-	119.2	ongoing
Subtransmission & Distribution	-	202.8	ongoing
Studies	-	95.3	ongoing
Other	-	16.2	ongoing
Total	-	779.2	

a/ Costs to finish the project. Total costs estimated at US$250 million.

Source: INECEL and Ecuador Public Investment review, World Bank - June 1985.

Table 5.4: RECOMMENDED INVESTMENT PROGRAM
IN THE POWER SECTOR, 1985-1988
(Million 1984 US$)

Project	INECEL'S Investment Program	Recommended a/	Recommended as % of Proposed
Generation	345.7	156.1	45
Agoyan	78.6	78.8	100
Paute "C"	183.3	58.4	32
Daule-Peripa	60.5	11.5	19
Paute-Mazar	23.1	0.0	0
Rehabilitation Thermal	-	7.4	-
Transmission & Substation	119.2	93.1	76
Subtransmission & Distribution	202.8	202.8	100
Studies	95.3	40.0	42
Other	16.2	8.0	49
Total	779.2	500	64

a/ By the Public Investment and Energy Assessment Missions.

Source: INECEL and World Bank.

5.36 Paute C. Given the complexity of the sedimentation problem in the development of the Paute River (paras. 5.11-5.16), it would be advisable to postpone civil works on the Paute C project until more information about sediments, including proposals for handling them, becomes available. 38/ To generate this information it would be necessary to engage experts in sedimentation, erosion, and hydraulics to find a solution to extend the economic life of the Paute-Amaluza reservoir. INECEL has ample time to assess the sediment problem, start construction of Paute C in 1986 or even in 1987, and still finish the project before 1994, when it might be needed.

5.37 Daule-Peripa is a multiple-purpose project with a hydroelectric component. The cost of the hydroelectric component, which is to be connected to the dam, would be about US$108 million (1984 prices); it would have an installed capacity of 130 MW (75 MW firm capacity) and an average energy output of about 400 GWh per year. This energy output, if produced in a thermal power plant, would require about 663 thousand barrels of bunker C. At a price of US$28.37/bbl. (1984 average price), the savings in fuel cost could be about US$19 million per year. In view of the present resource constraint and the fact that installed capacity would still suffice to meet peak demand in 1991, it would be advisable to defer construction of the hydropower component two years and start construction in 1989. Results of economic analysis have shown that the economic disadvantages of such a deferment would be marginal.

5.38 Transmission. Considerable transmission improvements are expected in the National Interconnected System (SNI) with the construction of the last section of the transmission ring (230 kV transmission line between Paute and Ambato) which is part of the expansion program for 1985-1989. Some 300 kms of 138 kV transmission lines are also included in the 1985-1989 expansion program. Those lines are expected to provide the links between the main transmission ring and other centers of consumption.

5.39 INECEL plans to invest US$130 million during 1985-1989 in the expansion of its transmission facilities. In view of their importance for fuel substitution, further electrification, improvement in system operation and loss reduction, these investments can be considered reasonable and should be maintained. In considering a reduction of transmission investments, the principal cuts therefore have concentrated on those lines and substations associated with deferred generation plans.

5.40 Subtransmission and Distribution. Plans are to integrate all isolated systems into the main SNI network through subtransmission lines of 69 and 34.5 kV. The responsibility for carrying out the expansion and

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38/ Even if the construction has started, the project could still be delayed according to the power demand requirements, INECEL's financial situation, and the country's priorities.

connection of the subtransmission and distribution systems, including rural electrification, lies mostly with the regional electric companies under the supervision of INECEL. With the exception of EMELEC in Guayaquil, all other 16 regional electric companies are subsidiaries of INECEL. The amount of investment allocated for subtransmission, distribution and rural electrification during the years 1985-1988 is estimated to be in the range of about US$200 million, a reasonable amount taking into consideration the low electrification rate in Ecuador.

Studies

5.41 INECEL's investment plans include various feasibility studies, mostly for new hydroelectric projects. Most of these studies are already under preparation or committed. They would also provide the basis for planning. It should be emphasized that certain studies are of the highest priority (i.e. Cardenillo and Sopladora) due to their effects on current decisions and should be maintained. Furthermore, if studies are to be ranked in order of priority, the mission suggests that emphasis should be placed on "small" projects (i.e. in the 100-300 MW range) that could provide for greater planning flexibility than the larger and riskier plants that ultimately can be more expensive. This is particularly important in Ecuador with its limited financial resources and macroeconomic constraints. An amount of about US$40 million, to be invested in studies during 1985-1988, would be adequate.

Institutional Problems

5.42 The sector has tried to implement a rational institutional structure by grouping together companies serving adjoining sections of the country. In practice, the new company has been formed but the old companies continue to exist. As a result, more concessionaires exist at present than when reorganization began.

5.43 INECEL is currently studying this problem and one of the major points on its agenda concerns the operational impediments discussed in para. 5.24. An alternative under study is to reorganize INECEL's operations so it would be able to circumvent a large amount of the legal constraints that bind INECEL at present. At the subsidiary level, plans for integrating companies into stronger units face political opposition at the local level and a solution is feasible only if the Government decides to back INECEL in its negotiations for liquidating the small enterprises.

5.44 In the early 1990s, INECEL's plans call for the simultaneous execution of up to four hydro projects. Given their present organization such a situation would tax management's capabilities above the level they could reasonably cope with. To control the execution of the expansion program it would be desirable to explore alternative types of organization for successfully managing the projects.

5.45 EMELEC's status is being negotiated and the future entity that would distribute power in Guayaquil could be either an INECEL-type of subsidiary with local investment, or an autonomous organization similar to the Guayaquil Port Authority. The latter possibility would create a utility that would be practically independent from INECEL and would not contribute to the efficiency of the sector.

Recommendations

5.46 The mission recommends that INECEL should take the following actions:

(a) Continue the analysis of the Paute Mazar project by taking into account all feasible alternatives to solve the silting problem;

(b) Execute as soon as possible the feasibility studies for Sopladora and Cardenillo to adequately assess the downstream benefits of Paute Mazar;

(c) Seek a solution to the sector's financial problems through a comprehensive agreement between INECEL, its subsidiaries and the Government. Such an agreement should contemplate (i) a plan for government contributions to the sector based upon country-wide priorities, (ii) a plan for tariff increases based on marginal cost analysis and consistent with the sector's financial plans, and (iii) a plan for exerting influence on INECEL subsidiaries to encourage them to comply with their obligations for supplementing INECEL supplies;

(d) Carry out a loss reduction study focussing initially on invoicing and theft problems;

(e) Proceed with the survey to determine institutional problems in the power sector and in INECEL itself. The survey would include a recommendation for a rationalization of the present functional structure and improvements of INECEL's present information systems.

(f) Seek a solution to INECEL's operating difficulties by organizing the present operational divisions in such a way that provisions for procurement are taken opportunely (i.e., larger stocks of spare parts);

(g) Analyze with anticipation the problems that may arise in managing several construction contracts for hydro plants and seek alternatives that will allow INECEL to execute the projects efficiently;

(h) Seek greater coordination between INECEL and INE in demand projections and with CEPE in relation to gas availability.

VI. FUELWOOD

Background

6.1 Although deforestation is not a major national issue in Ecuador, real and growing regional fuelwood supply deficits occur, especially in the southern half of the central Sierra region. The current GOE forestry program has no direct energy component to address this supply problem, and the small existing remedial programs funded by various international aid donors are too small and not coordinated at the national level. Because of the low cost of alternative fuels and the relative abundance of fuelwood, there have been no major conservation initiatives in this sector. While the presence of a regional supply problem can be acknowledged, it has not yet been adequately quantified.

6.2 The predominant use of fuelwood in Ecuador is in the household energy sector. The overall contribution of fuelwood to the total 1984 national energy demand is approximately 20%. This contribution has dropped significantly from 48% in 1970 and 35% in 1975 because of the infiltration of low-cost convenience fuels (kerosene, bottle gas, low-octane gasoline, and electricity) into the sector in both urban, and to a more limited extent, rural areas.

Fuelwood Consumption

6.3 A breakdown of the residential consumption by geographic sector was calculated by INE as 2.1 kg per person per day in the Sierra, 1.9 kg per person per day in the Coastal region, and 2.9 kg per person per day in the Oriente. The heavy consumption in the Oriente must be prefaced by the facts that population is very low -- about 3% of the country's total, and that fuelwood from native forests far exceeds the population demands. A small difference is observed between consumption in the hot coastal region and the cool Sierra region, where wood is used for household heating and cooking. The narrow spread would appear to be an indicator that while needs are greater in the Sierra, supplies are extremely scarce in some areas, holding down the average consumption value. The coastal region is assumed to have a reasonable supply-demand balance for the near term.

6.4 In 1984, Ecuador consumed 854,000 toe of fuelwood of which the residential consumption of fuelwood was estimated at 680,000 toe (80%), concentrated in the rural areas. The demand for fuelwood for industrial users, including charcoal production, was estimated at about 170,000 toe for 1984. As the market for charcoal has evolved into the specialty market of restaurants and others, its contribution to the total national energy consumption has been estimated at not more than 1% of the total.

6.5 A large industrial fuelwood user in Ecuador is the brick industry. There are about 300 wood-burning brick kilns in Ecuador that consume, at full capacity, 108,000 m^3 p.a. 40/ 41/ The balance of the industrial demand is made up of small bakeries, small farmer crop drying, and fuel supplementation in the sugar industry. 42/

6.6 The average price for fuelwood in Ecuador is about 1 sucre per kg. Fuelwood and charcoal prices in Ecuador show a great discrepancy. Industrial users pay as little as 0.75 sucres per kg, while suburban Quito homeowners can pay as much as 3.5 sucres per kg to burn wood in fireplaces. Charcoal shows an equivalent spread in prices with retail prices in Quito being as high as 10 sucres per kg and prices in the more rural areas being as low as 3 sucres per kg.

6.7 When using the cost of useful energy, kerosene becomes the lowest cost fuel in Ecuador (see Table 2.1). However, the free collection of fuelwood is a major constraint to the use of kerosene stoves. A reversal may occur since now roughly 50% of household fuelwood users have to purchase wood, up from 24% in 1979. Kerosene stoves are now increasing in urban and wood deficit areas. As a result, the mission recommends an economic analysis to compare a woodstove program with kerosene stoves.

Projected Demand

6.8 The level of absolute demand for fuelwood is expected to remain relatively stable until 1990 and then to drop at an estimated 1% per year. Fuelwood demand for the next ten years will be determined by the magnitude of further price increases for petroleum based fuels, 43/ the overall rate of population growth, and urban migration. Fuelwood demand beyond 1995 will be a function of reforestation activities which to date are not well defined for energy purposes.

40/ Assuming 15 m^3 of fuelwood per kiln per cycle, and 24 cycles per year.

41/ Based on an INE survey of 43 brick makers in the Quito area, the brick industry is presently operating at one-third capacity or less.

42/ The sugar factories are also consumers of heavy fuel oil; one factory burns exclusively fuel oil and exchanges bagasse for fuel oil with a paper making processor.

43/ INE has estimated that at least 42% of the rural inhabitants now possess a stove capable of burning kerosene, LPG, or gasoline.

Supply Sources and Relative Availability

6.9 Although the longest supply line for fuelwood in Ecuador is estimated to be less than 50 km from wood source to end user, localized regional deficits are growing. Although extension in this distance can be tolerated for years before viability is lost, increased transportation costs will drive up the costs of delivered fuelwood. Currently, transportation accounts for 30% to 40% of the retail price of fuelwood. With a deforestation rate from all causes estimated at 400,000 ha/yr., and with a current reforestation rate of 5,000 to 10,000 ha/yr., the extinction of forest resources becomes a projectable reality. In addition, the choice of species and sites in current reforestation activities are questionable for direct energy application. The forest resources of Ecuador are estimated in Table 6.1 below.

Table 6.1: REMAINING FOREST RESOURCES OF ECUADOR

Forest Type	Area (ha)
Tropical humid	8,528,000
Tropical dry	420,000
Sub-tropical humid	2,754,000
Mangrove	120,000
Plantations a/	53,000
Total	11,875,000

a/ Plantations established between 1970 and 1983

Source: INE, 1985.

6.10 The majority of the remaining forest resources are in the Oriente region and in the northern half of the coastal region. The Sierra is the only region with a serious fuelwood deficit, and there in only the southern half. This is not to say that deforestation is not a problem. The unmanaged conversion of forest to agricultural land, commercial timbering operations, and the regional lack of wood for all purposes, contribute to a serious problem of deforestation. The problem is somewhat tempered by the fact that the species Eucalyptus Globulus was introduced into Ecuador over 100 years ago and is found throughout the Sierra. While this species does coppice well in Ecuador, the effect of altitude and temperature limit it to a maturity span of 10 to 15 years, and the remaining supply now cannot keep up with annual demand.

Organization of the Forestry Sector

6.11 The Ministerio de Agricultura y Ganaderia (MAG) does not consider reforestation a priority item. As a result, the Programa Nacional

Forestal (PRONAF) does not obtain adequate support from MAG. PRONAF was established to manage the forestry sector and government forest lands. Hoever, lack of coordination, plus insufficient funding and manpower, has prevented PRONAF from having an effective impact on the sector, especially in the area of reforestation. While both INE and PRONAF are directly involved in small projects to conduct species trials and establish small plots at altitudes up to 3,500 m where trees of any kind are extremely scarce, there is no coordination betwen the two organizations. In addition, the executive director of PRONAF has no direct access to the Minister and the district chiefs cannot get directly to decision-makers within PRONAF. The mission has recommended a reorganization of PRONAF as shown in Annex 14.

Reforestation Programs

6.12 The reforestation history in Ecuador is one of little success, and has not included any direct energy component. Since 1970, government reforestation programs have resulted in no more than 60,000 ha being planted, with private efforts achieving about half that amount. The current five-year plan for reforestation is optimistic based on past performance. 44/ With three major components encompassing 64,500 ha of production forest, 30,000 ha of environmental protection, and 25,000 ha of highway buffer, the only energy component in this program is indirect in terms of hydro watershed protection. There are manpower constraints both in PRONAF headquarters and in district offices which are aggravated by the inefficient institutional organization of PRONAF. The FONAFOR funds must be filtered through the Central Bank or Development Bank, making access to the funds potentially difficult. Private sector involvement is critical, especially in the forestry production area. Table 6.2 presents a breakdown of the FONAFOR/PRONAF program on a provincial basis. This optimistic program, which requires a replanting rate of about 5 to 6 times that achieved over the past 14 years, faces many obstacles in the course of fulfillment.

6.13 Private sector reforestation activities are currently estimated at 4000 to 6000 ha per year. The private enterprise association, Asociacion Industriales Madereros, is very active in trying to promote reforestation activities and could provide sufficient motivation and pressure to meet the reforestation goal.

6.14 There are small internationally-funded reforestation programs under way that have energy components; however, most projects are aimed at high value species such as Pine, and have markets other than fuelwood in mind.

44/ It is financed by a tax on petroleum exports.

Table 6.2: FIVE-YEAR FONAFOR REFORESTATION PLAN; 1984-1988

Production Plantations			Environmental Protection Plantations		
Project	Hectares	Cost	Province	Hectares	Cost
		(10^6 Sucres)			(10^6 Sucres)
Carchi-Imbabura	10,000	250.0	Carchi	520	13.0
Pichincha-Cotopaxi	21,000	525.0	Imbabura	4,200	105.0
Chimborazo-Tungurahua-Bolivar	15,000	375.0	Pichincha	9,100	231.0
Loja	9,000	225.0	Tungurahua	1,620	40.5
Cañar	1,000	25.0	Chimborazo	1,350	31.0
El Oro	1,000	25.0	Bolivar	600	15.0
Los Rios	1,000	30.0	Cañar	2,500	62.5
Esmeraldas	500	7.5	Azuay	3,500	87.5
Napo	1,500	22.5	Loja	1,620	48.0
Pastaza	1,000	15.0	El Oro	1,500	45.0
Morona Santiago	1,500	22.5	Los Rios	1,200	36.0
Esmeraldas-Manabi-Guayas	2,000	30.0	Esmeraldas	2,290	35.0
Subtotal	64,500	1,957.5	Subtotal	30,000	749.5

Highway Buffer Plantings complete the reforestation along 2000 km of roads, covering an area of 25000 ha. Total cost of the program 3358 million sucres.

Source: "Informe a las Bases", Hugo de Caicedo.

Investment Priorities

6.15 From a preliminary analysis, the mission does not consider investments in reforestation for energy purposes to be a priority for the short term. It has been found that the opportunity cost of fuelwood (when energy efficiency is taken into account) is more than twice that of kerosene. This is due to the high reforestation costs in Ecuador associated with poor terrain and harsh climate in the deforested areas such as in the southern Sierra. The mission considers that before any major reforestation program is undertaken, a detailed benefit/cost analysis should be made comparing a reforestation program for energy purposes with kerosene utilization.

Recommendations

6.16 The mission recommends that INFOR and PRONAF should take the following actions:

(a) Determine the magnitude of the fuelwood deficit in the Sierra.

(b) Update the 1979 INE report on fuelwood consumption in the rural sector, but with a focus only on the southern Sierra region. The local supply-demand balance must be defined using field surveys and census data.

(c) Include energy components in the nation's reforestation program tc ensure long-term fuelwood supply in the deficit areas.

(d) Reorganize PRONAF to ensure proper coordination and communication at all levels.

VII. NON-CONVENTIONAL ENERGY SOURCES

7.1 This chapter analyzes the complementary non-conventional energy sources of interest for Ecuador, concentrating on geothermal, small hydro for rural areas, solar energy, wind energy, biogas, bagasse, other crop residues, and small wood-fired electric systems. The greatest constraint to the development of these non-conventional resources in Ecuador is the low subsidized prices of alternative commercial fuels found in the country.

Geothermal

7.2 There are two sectors which could benefit from geothermal development in Ecuador: the power sector, normally requiring high temperature fluid sources; and the industrial process heating sector, which can use lower fluid temperatures. Initiatives are underway in both sectors with OLADE and INECEL focusing on the power sector, and INE coordinating work for the industrial sector.

Power Applications

7.3 Given the largely untapped hydroelectric potential in Ecuador, a preliminary analysis would normally rate the geothermal potential as second priority. However, this may not necessarily be the case in Ecuador as a result of the siltation problem (see paras. 5-11-5.12), which can severely reduce the working life of any given sized reservoir unless costly remedial actions are taken. When the costs of all the remedial adjustments are considered (secondary dams, protection reforestation, water intake protection), the true cost of production for the hydro projects can be substantially higher. In this context, the use of geothermal energy for power applications becomes an interesting alternative.

7.4 Ecuador has good potential for developing geothermal energy for the power sector, and further feasibility activities are warranted. The Italian government, in cooperation with the GOE, is financing a prefeasibility study for an eventual 50-100 MW 45/ power station in the Tulcan-Chiles region in Carchi province. The prefeasibility work 46/ will complete extensive geophysical analysis and also undertake the drilling of some small diameter, shallow test wells of up to 400 m. Assuming satisfactory findings with the test wells, a full feasibility study could commence shortly after completion of the current work.

45/ INECEL's plans call for a 10 MW plant as a first step.

46/ Scheduled to be completed by end of 1985.

7.5 INECEL is also considering prefeasibility studies in two other Sierra provinces, Imbabura and Cotopaxi. While the Japanese government has expressed interest in funding such work near Cotacachi in the Imbabura province, no outside funds have yet been committed to either site. Based on the superficial evidence available, the overall goethermal power potential has been estimated by INE around 60,000 MW. However, geothermal can not be considered as a firm resource until the prefeasibility study is completed for the Tulcan-Chiles region.

7.6 As no geothermal wells yet have been drilled and the character of fluids revealed, accurate cost of production figures for geothermal plants cannot be estimated. Given this uncertainty, it would appear appropriate to carry the current Tulcan-Chiles geothermal evaluation all the way through feasibility confirmation. The feasibility study output would include sufficient resource definition and characterization to allow an accurate estimate of cost, and provide the opportunity to proceed directly to project implementation if the cost of the project made it competitive with further hydro development.

Industrial Process Heat Applications

7.7 The second option for using geothermal energy in Ecuador is in industrial process heat where lower temperature fluids, which are not normally suited for power production, can be directly substituted for process heat now produced by electricity or the combustion of petroleum fuels. Because of the low prices of the competing fuels, an objective program evaluation will be needed by end 1985 to determine the merit of any further spending in this area; this is included in para. 30 under the technical assistance requirements. INE, using EEC funded energy planners and additional study funds from organizations such as USAID, has developed a program for industrial process heat substitution in the five major industrial areas. Thus far, only the Quito and Cuenca areas have been evaluated and reported in detail. For both, some geophysical evaluations have been performed and an industrial survey completed. INE is focusing on the area of the Valle de los Chillos, about 15 km from Quito, in trying to promote a demonstration project. With USAID funding, INE hopes to identify an appropriate site, possibly near La Cerveceria Andina (brewery), where a shallow test well can be drilled in 1985. While the potential for substituting geothermal heat for oil in the Valle de los Chillos could approach 4,000 toe per year, there are significant obstacles to overcome. The industrial base in the Valle de los Chillos is not concentrated, and the dispersed nature inhibits development.

7.8 The low price of diesel and fuel oil currently provides no financial motivation for the heat users to convert to geothermal, as preliminary estimations for paybacks are 7 years if 500m wells can be used, and 14 years if 1,500 m wells are needed to obtain the desired fluids temperature of 95°C. However, when compared to the opportunity cost for fuel oil of US$0.61/gal., the above paybacks fall to 2.65 and 5.3 years -- a more reasonable commercial case. The well costs are estimated at about US$500,000 for a 500 m well and US$1 million for a 1,500 m well. By the end of 1985, the prefeasibility efforts should be completed for the Valle de los Chillos, and an objective evaluation can be made either to proceed with demonstration or terminate the activity. 47/

Small Hydro For Rural Areas

7.9 The existing small hydro program coordinated by INE has merit for extending the availability of electricity in rural areas where grid extension is not technically or financially feasible. The development of low-cost, made-in-Ecuador hydro turbines and control systems is important for making these items competitive with the diesel systems normally used for remote rural electrification. Assuming a plant is scheduled to be built, the substitution of such a program for diesel oil will be small because of the small unit size. The perceived social impact of rural electrification programs is, however, large. USAID funds have been, and are, wisely used for this program. The resulting successful 50-kW Apuela demonstration plant has provided the design basis for a standard line of turbines to be manufactured locally in eight sizes from 20 kW to 150 kW.

7.10 While the current INECEL rural electrification program has only limited applications planned, there are probably more than 150 feasible sites in Ecuador, according to INE. INE could survey the sites and develop a proposal for an accelerated implementation, and even solicit donor funds for such a rural development program.

Economic Comparison

7.11 Fifty 100-kW systems could be installed for about US$2 million. 48/ The capital cost required to install the same capacity in small diesels would approach US$4 million so that US$2 million less would be required to implement the small hydro program based on in-country manufacture of turbine and controls. With a combined use factor 49/ of 40%, 17.52 million kWh could be generated per year. Comparable diesel plants at 25% efficiency would produce 10.4 kWh per gallon of diesel. Therefore, the fifty small hydro plants would represent 1.68 million gallons of diesel oil per year valued at US$1.46 million at the opportunity cost of the diesel oil and US$622,000 at the retail price of diesel.

47/ Sufficient criteria for making a decision will not be available until at least late 1985 when geophysical studies will have been interpreted by experts, and fluids obtained from a test well will have been thoroughly analyzed.

48/ Assuming US$400/kW as in the Apuela (50 kW) experience.

49/ Average load factor and down-time considered.

7.12 INE's performance in this program has been good, and it can serve as a model for INE's efforts in other technology areas, and as a model for scaling up this low cost hydro option to, possibly, 300 kW in unit size. The program is cost effective in Ecuador for a relatively well-defined technology area. INE has searched internationally for the right technology application to pursue, modified it appropriately for the country context, and demonstrated it successfully.

Solar Energy

7.13 Solar radiation in Ecuador is an available resource technically suitable for thermal and photovoltaic applications. A major drawback to its use in thermal applications is that conventional methods of producing hot water are very inexpensive in Ecuador, from the viewpoint both of capital investment and operating expense. Photovoltaics are also too expensive compared to the competing sources.

7.14 Radiation data in Ecuador has been reasonably well monitored, and sufficient information is available for purposes of designing commercial systems. Annual average radiation values vary regionally (and to a certain extent, seasonally) from 2,800 watt hours/m^2 per day to 4,700 watt hours/m^2 per day.

Thermal Applications

7.15 Although there are nine private firms in Quito and five in Guayaquil that are offering solar thermal systems commercially, their penetration of the market is inhibited by price competition with competing technologies. While the main product line is for domestic water heating, applications for industrial process and crop drying products are also available. For the past five years, the national domestic solar water heating market has been about 100 units per year. The units available are either totally produced from local materials, or assembled locally from imported components. Both thermo-syphon and pumped type systems are offered. The typical domestic water heating system sold has 60 gallons of water storage and 2.8 m^2 of collector surface, and costs between US$500 and US$600.

7.16 As diesel oil and fuel oil are relatively low priced, both the household water heating and industrial process heating markets are firmly entrenched in the use of traditional energy sources and no real market exists in this area for solar technology. While diesel oil has a unit useful energy cost of USȼ1.6/kWh, a thermosiphon solar water heating system rates at USȼ10.9/kWh, as shown in Tables 7.1 and 7.2. Therefore, there is insufficient financial incentive for either existing households to switch over or for new home builders to provide solar hardware under the current circumstances.

Table 7.1: CONVENTIONAL WATER HEATING FUEL COSTS IN ECUADOR

Fuel	Heat Value	Conversion Factor	Process Efficiency	Unit Useful Energy Cost
	(kcal/kg)	(kcal/kWh)	(%)	(US¢/kWh)
Industrial Purposes				
Diesel Oil	11,100	860	65	1.6
Household purposes				
Electricity			95	3.5

Source: Mission estimates.

Table 7.2: SOLAR WATER HEATING COSTS

System	Collector	Useful Life	Unit Cost
	(m^2)	(year)	(US¢/kWh)
Industrial purposes			
Pump-assisted system	920.00	15	3.7-5.4
Household purposes			
Thermosiphon system	2.6	15	10.9
Pump-assisted system	2.41	5 a/	5.8

a/ Using plastic materials.

Source: Mission estimates

Photovoltaic Applications

7.17 Photovoltaic applications for solar energy are not economically attractive for widespread use in Ecuador. The typical investment cost is approximately US$10-15 per peak watt and its useful life is about 20 years. Its use should be restricted to very remote areas for possible applications such as telecommunications, navigational aide, public health lighting and refrigeration, and possibly water pumping or desalination. Preferable applications would be characterized by low electricity consumption.

INE's Solar Energy Program

7.18 INE has spent considerable cash and manpower resources on solar thermal technologies which are already commercially available. The commercially available hardware is significantly more expensive than what is found in Ecuador. INE's focus on solar energy is rightfully on trying to develop an extremely inexpensive technology base that can compete against the low energy costs experienced in Ecuador. If the solar energy program is to be continued in Ecuador INE should use its own approach developed for small hydro, and research what is available for technology transfer in other regions experiencing a similar situation. There are opportunities in Ecuador for such systems in low cost public housing and in many other urban dwellings; however, the technology transfer time and cost can be reduced substantially with less manpower demand on INE.

Wind Energy

Wind Water Pumping

7.19 Wind water pumping applications are not financially attractive at this time in Ecuador because of the low cost of the diesel alternative. Several areas in the Sierra provinces of Carchi, Pinchincha, and Cotopaxi plus an area in the Galapagos were reported to have average wind speeds greater than 18 km/hr. However, at the present cost of diesel oil, US$0.41 per gallon (US¢10.0/kWh), it is estimated that even a mean annual wind speed of 22.5 km/hr is not competitive. 50/ Table 7.3 compares wind velocity with windmill water pumping energy costs.

Table 7.3: WINDMILL WATER PUMPING ENERGY COSTS

Mean Annual Wind Velocity (km/hr)	Mean Energy (kWh/m^2)	Rotor Area (m^2)	Efficiency (%)	Annual Useful Energy (kWh)	Unit Cost (US¢/kWh)
12.09	673.1	2.63	30	531.1	52.5
16.1	995.5	2.63	30	785.4	35.5
19.3	1,744.1	2.63	30	1,376.4	20.3
22.5	2,512.3	2.63	31	1,982.2	14.1

Source: Mission estimates.

Electricity

7.20 The situation for wind-driven electricity generators is not promising, either. The typical cost of this application is about US¢25.0/kWh (for 12% annual discount rate and 15 years of useful equipment life) for mean wind velocities of about 19 km/hr. This may be compared to other alternatives such as US¢8.4/kWh for diesel and US¢3.4/kWh for the INECEL interconnected system. Due to the high cost this use should be very limited.

50/ At the opportunity cost of US$0.86 per gallon for diesel oil, a wind speed of over 19 km/hr would be competitive.

Biogas

7.21 At an average cost of US$125 per m^3 digester capacity, the use of biogas is not competitive in Ecuador with diesel oil, kerosene, or electricity. Nevertheless, the work of INE, OLADE and others in biogas production in Ecuador has made a significant technology base available. There are currently 28 units 51/ in operation (at least installed), averaging 12 m^3 in size. The majority of the units are designed on Indian technology using cattle manure as the feedstock, although units for other animal and/or crop residues have been attempted. The primary market would appear to be those farmers with 15-50 head of cattle who perceive the decontamination and fertilizer production value of the process to be as important as the energy production. However, it is unlikely that biogas will play a significant role in the energy sector. Since the commercial fuels are heavily subsidized, the dispersion of agricultural activity in Ecuador is great, and the cost of collecting vegetable and animal wastes is high.

Other Biomass Energy Sources

Bagasse

7.22 The depressed world sugar market and the low cost of fuel oil and diesel oil are effectively inhibiting the further exploitation of bagasse in Ecuador. Bagasse has traditionally been a significant contributor to Ecuador's industrial energy sector. In 1978 it represented 32% of that sector's energy consumption, at 186,000 toe. By 1984 the contribution dropped to 20%, at 152,000 toe. This 1984 value is somewhat misleading as the total bagasse production of the largest sugar producer, San Carlos, is delivered to its neighbor, Papeleria Nacional, for paper making and is not available as an energy source. Therefore, the true energy contribution of bagasse is lower. As a compensation, San Carlos currently receives 1 kg of fuel oil from the Papeleria Nacional for each 3.6 kg of bagasse it delivers, which is the thermal equivalent.

7.23 The Ecuadorian sugar industry is also a net user of commercial fuel to supplement its use of bagasse. In 1984 it is estimated that the sugar industry consumed an additional 8,000 tons of fuel oil and 1,000 tons of fuelwood. This suggests that the efficiency of the industry is far from optimum. Conservation initiatives and processing improvements could result in making the sugar plants become not only energy self-sufficient but also net exporters of energy in the form of electricity or, possibly, even bagasse briquettes. Under current conditions and for the foreseeable future, bagasse is not expected to make any increased

51/ Including four large units, of which the largest is 180 m^3.

contributions to the energy sector as no motivation exists to make the necessary investments.

Other Crop Residues

7.24 The agricultural sector of Ecuador produces signiifcant quantities of residues which under diferent conditions, such as higher national energy prices, could be considered as alternative fuel resources. Table 7.4 shows the relative availability of crop residues in 1980.

Table 7.4: AVAILABILITY OF CROP RESIDUES IN 1980

Crop	Residue
	(Tons per Year)
Rice	428,000
Barley	123,000
Wheat	106,000
Corn	2,205,000
Cacao	82,000
Coffee	62,000
Total	3,006,000

7.25 Approximately one half of the total, or 1.5 million tons, could reasonably be considered as an energy source, leaving the other half for animal feed, soil protection, etc. At a calorific value of 13,500 MJ per ton, this represents an energy input value potential of about 500,000 toe. While this is an impressive number, there are many inhibiting factors in pursuing it as an energy source. The harvesting, grinding and briquetting needed to get it into a transportable and useable form are estimated to cost at least US$30 per ton, making it very expensive compared to current options. The agricultural production is also very dispersed, where a concentrated producing area would be the ideal. The necessary conclusion is that, although the resource is there, it is not financially viable enough to be considered as a usable energy source. No significant contribution to the energy sector can be expected in the foreseeable future in Ecuador.

Small Wood-Fired Electric Systems

7.26 For small popultion centers in remote areas, where grid extension is not feasible and no hydro resources exist, small wood-fired power systems could be economically attrative in the Oriente region where an abundant fuelwood resource is found. The wood-fired option can normally produce power for about half the price of competing diesel fired systems, if world market prices are being paid for diesel fuel. Compared at the retail price of diesel in Ecuador, however, wood-fired systems would be at best a breakeven option.

7.27 The GOE is currently investigating the use of gasifier-internal combustion engine systems for this application. The small scale evaluation of the gasification technology is warranted at this time, although consideration of any program for widespread commercial implementation is premature. With INE coordination, a small 20-kW system has been installed and operated at the Escuela Politecnica in Guayaquil. For remote installations in Ecuador, gasification technology can only be considered as having very high risk for current applications, but good potential for the future. Gasification offers the potential avantage of relatively high efficiencies in small size ranges, above 20% overall for 100 kW and above, compared to the normally used wood-fired steam power systems which would be below 10% at this size. The efficiency difference narrows as size increases, and steam plants become cost competitive with gasification systems at plant capacities somewhere between 500 and 700 kW. For applications above 1 MW, wood-fired steam systems appear to have definite financial advantages.

7.28 The negative side of using wood-fired power systems is that such use could be considered counter-productive to forest conservation initiatives that are necessary to stop rampant deforestation, even in the Oriente. The ideal application is a managed one where residues such as commercial logging or sawmill wastes are utilized as the fuel for the power plant. In a resource-abundant area, these normally go to waste. Here the application will be cost competitive with even the low priced Ecuadorian diesel fuel, and easily can be proven as not environmentally detrimental.

Role of INE

7.29 INE, as the national energy planning center, has the organizational responsibility for energy planing and for coordinating research, development, demonstration and technology transfer activities with a focus on nonconventional energy resource applications and conservation.

7.30 INE, as the national energy planning center, appears to have placed much emphasis on areas with low pay-off on a national scale. 52/ INE's performance can be attributed directly to the political sensitivities surrounding the major energy issues such as energy pricing and increased exploration activities, and the political vulnerability of

52/ INE has recently shifted its main emphasis to more important energy issues, i.e., studies on expansion of the refineries and energy pricing.

the institution. In practice, the role of INE depends largely on the personal relations established between its staff and people that work in the rest of the energy sector rather than on institutional links.

7.31 Activities such as small hydro have been worthwhile. The small hydro program coordinated by INE has great potential for extending the rural electricity availability in the most cost effective means possible. This is a well structured and well carried out program that INE itself should analyze for applying its methodology to other areas such as solar energy. INE can now focus on an implementation program for small hydro units in close coordination with INECEL and regional governmental authorities.

7.32 The program being carried out by INE for geothermal process heat applications using EEC technical advisors and some USAID funding is ideally directed at substituting geothermal fluid heat for process heat derived from combustion, and as such could have positive national economic implications. The problem remains that low competing energy prices remove any incentive for the private industries to incorporate geothermal fluids in their process heat systems. Without addressing the major issue of energy pricing, the geothermal activity can only result in a dead-end, with a technically implementable alternative that is not financially viable, even though it would produce economic benefits to the country.

7.33 INE needs to change its perspective. INE, as the national energy planning organization, should put its major focus on the most important energy issues of the country. In order to provide greater stability to INE personnel and to allow more continuity in the works and studies realized by this organism, INE's wages should be brought up to the average of the rest of the energy sector.

Annex 1

ECUADOR OVERALL ENERGY BALANCE - 1984
(Thousand TOE)

	Non-Commercial Energy	Commercial Energy: Crude Oil	Commercial Energy: Petroleum Products	Electricity: Hydro	Electricity: Thermal	Electricity: Total	Commercial Energy Total	Total Commercial and Non-Commercial
Primary Supply:								
Production	1,002	13,475		273		273	13,748	14,750
Exports		(8,935)						(8,935)
Imports								
Total	1,002	4,540				273	4,813	5,815
Transformation:								
Refineries		(4,540)	4,385					
Thermal Plants			(310)		90	90		(220)
Energy Sector		(137)	(226)					(363)
Losses		(18)				(90)		(108)
Product Trade:								
Imports			512					512
Exports			(1,122)					(1,122)
Domestic Supply:	1,002		3,239			273	3,512	4,514
Final Consumption:								
Industry	152		537			90	627	779
Transportation			1,751					1,751
Households	850		451			180	631	1,481
Agriculture			157					157
Others			343			3		346

Source: Mission estimates.

EXPORTABLE CRUDE OIL PRODUCTION, 1985 TO 2000

Exportable crude oil volume has been estimated in the following way: 99% of crude oil production minus domestic consumption. (Losses and crude oil consumption by the petroleum sector amount to 1% of the production.)

The value of possible crude oil exports is estimated on the basis of an international price of Ecuadorian crude at US$27/bbl, through the year 2000.

		Exportable Surplus					
		Constant Prices		+50%		+100%	
	Production	volume	value	volume	value	volume	value
	(1000t)	(10^3t)	($10^6$$)	(10^3t)	($10^6$$)	(10^3t)	($10^6$$)
Low Case Scenario:							
1985	14471	10332	1951	10705	2021	10750	2030
1990	18778	13295	2510	13924	2629	14239	2688
1995	16467	9283	1753	10290	1943	11009	2079
2000	13708	4267	806	5825	1100	7131	1346
High Case Scenario:							
1985	14471	10234	1932	10618	2005	10697	2020
1990	18778	12465	2354	13267	2505	13870	2619
1995	16467	7135	1347	8659	1635	10162	1919
2000	13708	-150	-28	2599	491	5584	1054

Source: Mission estimate.

ESTIMATION OF THE SLATE OF REFINERIES OUTPUT AND OF DOMESTIC PETROLEUM PRODUCTS DEMAND, 1985 TO 2000

1. Estimation of refineries output capacities, 1985-2000
(thousand toe)

	1985	1990	1995	2000
LPG	138	201	208	243
Gasolines	1007	1382	1462	1944
Kerosene/Jet fuel	542	649	678	891
Diesel oil	744	1088	1180	1539
Fuel oil	2122	2530	2530	3483
Total	4553	5850	6058	8100

Source: Cepe and mission estimates.

2. Estimation of the slate of domestic petroleum products demand, 1985-2000 (thousand toe)

Low case scenario

		Gasolines	Kero/jet	Diesel	Fuel oil	LPG	Total
1985	I	1382	451	935	954	272	3994
	II	1159	362	941	906	253	3621
1990	I	1668	593	1281	1314	439	5295
	II	1353	467	1306	1167	373	4666
1995	I	1930	765	1720	1916	688	7019
	II	1563	601	1683	1624	541	6012
2000	I	2242	968	2242	2829	1023	9304
	II	1858	775	2169	2169	775	7746

High case scenario

		Gasolines	Kero/jet	Diesel	Fuel Oil	LPG	Total
1985	I	1391	409	982	1023	286	4092
	II	1186	371	890	964	297	3708
1990	I	1838	613	1470	1714	490	6125
	II	1544	532	1278	1543	426	5323
1995	I	2291	917	2292	2842	825	9167
	II	1911	764	1834	2446	688	7643
2000	I	3019	1235	3430	4665	1372	13721
	II	2304	987	2744	3840	1097	10972

For each scenario, two cases are considered: I, constant petroleum products prices; II, increase in petroleum products prices of 50% and

For the Low case I scenario, the slate of demand is taken from: CEPE. Proyeccion de la Demanda Interna de Derivados de Petroleo Periodo 1984-2000.

For the other scenarios, the slate has been estimated.

Source: CEPE and mission estimates.

3. **Estimation of the share of petroleum products surplus or deficit, 1985-2000** (thousand toe)

The exportable surplus or deficit has been calculated, for each product, as: refineries output minus domestic demand.

Low case scenario		Gasolines	Kero/Jet	Diesel	Fuel oil	LPG	Total
1985	I	-375	91	-191	1168	-134	559
	II	-152	180	-197	1216	-115	932
1990	I	-286	56	-193	1216	-238	555
	II	-29	182	-218	1363	-172	1126
1995	I	-468	-87	-540	614	-480	-961
	II	-101	77	-503	906	-333	46
2000	I	-298	-77	-703	654	-780	-1204
	II	86	116	-630	1314	-532	354

High case scenario		Gasolines	Kero/jet	Diesel	Fuel oil	LPG	Total
1985	I	-384	133	-238	1099	-148	462
	II	-179	171	-146	1158	-159	845
1990	I	-456	36	-382	816	-289	-275
	II	-162	117	-190	987	-225	527
1995	I	-829	-239	-1112	-312	-617	-3109
	II	-449	-86	-654	84	-480	-1585
2000	I	-1075	-344	-1891	-1182	-1129	-5621
	II	-360	-96	-1205	-357	-854	-2872

Source: Cepe and mission estimates.

4. Estimation of the value of petroleum products surplus or deficit, 1985-2000 (million US$)

The exportable surplus or deficit is valued at $28/bbl, being the price of crude oil plus a $1/bbl refining cost. Thus, the global value of potential petroleum products exports from Ecuador is as follows:

		Constant prices	+50% in prices
Low case scenario	1985	114.0	190.1
	1990	113.2	229.6
	1995	-196.0	9.4
	2000	-245.5	72.2
High case scenario	1985	94.2	172.3
	1990	-56.1	107.5
	1995	-634.0	-323.2
	2000	-1146.3	-585.7

Source: Mission estimates.

Annex 3

ESTIMATION OF THE COST OF PETROLEUM PRODUCT CONTRABAND IN 1984

	Volume of Contraband (1)	Domestic prices 1984 (2)	International pri es (3)	Income from domestic sales (1) x (2) (4)	Income from exports (1) x (3) (5)	Losses from Contraband (5) - (4)
	(10^6 gal.)	($/gal.)	($/gal.)	(10^6 $)	(10^6 $)	(10^6 $)
Gasolines	78.4	0.31	0.78	24.3	61.2	36.9
Kerosene	10.7	0.14	0.85	1.5	9.1	7.6
Diesel oil	8.8	0.22	0.86	1.9	7.6	5.7
Fuel oil	14.3	0.13	0.61	1.9	8.7	6.8
TOTAL	112.2			29.6	86.6	57.0

Source: INE and Mission estimates.

MARGINAL COST AND TARIFF ANALYSIS

(a) Marginal Cost Analysis

1. Generation Costs: These were calculated using the results from INECEL's expansion planning programs and were cross-checked with an incremental cost approach. They show the following pattern:

	Peak	Off-Peak
Energy Cost (USc/kWh)	62	26
Capacity Costs (US$/kW per year)		
1985-1993	58	---
1994-2001	90	---

Peak hours are defined within the 1800h-2200h period, 365 days a year.

2. Transmission Costs: These comprise 230 kV and 138 kV lines together with their associated substations. The incremental transmission cost is on the order of 50 US$/kW per year.

3. Subtransmission and Distribution: The incremental cost of this component is on the order of $60/kW per year.

(b) Tariff Analysis

Present Tariffs

1. Tariffs can be divided into two categories: High Voltage (HV) rates that apply to sales between INECEL and its subsidiaries and final customer tariffs.

2. HV Tariffs have the following components (1985 average)

Capacity Charge: $US24/kW year
Energy Charges (USc/kWh):

Contracted Energy	1.48 (varies with load factor)
Substitution Energy	1.29
Emergency Energy	2.05

3. Consumer tariffs are structured by sectors. Large industrial and commercial users have demand as well as energy charges (the latter vary according to load factor). Capacity charges range between US$9 and US$22/kW-year and the respective energy charge varies between 4.2 and 2.1 USc/kWh. Low voltage consumers have block-structured tariffs with energy charges ranging from 1.0 to 4.2 USc/kWh. The following table summarizes some average typical electric bills in USc/kWh discriminated by Sierra and Coastal utilities:

Typical Average Bilis (US¢/kWh)

Small LV Consumers	kWh/mo.	Sierra	Coast
Residential	60	1.1	1.7
	200	3.6	4.2
Commercial	60	1.8	2.1
	350	4.0	4.2
Industrial	---	3.2	3.8

Large Industrial and Commercial Users:

	Load Factor (%)	Sierra	Coast
Commercial	23	4.7	4.7
Industrial	23	3.7	4.0
	63	3.3	3.6

Reference Marginal Cost Tariffs

4. Based on the marginal cost analysis, the following tariff structure were calculated as benchmarks for suggesting policy changes:

	Energy (US¢/kWh)	Capacity (US$/kW-year)
A - INECEL Tariffs		
Peak	6.4	107
Off-Peak	2.7	---
B - MV Customers with double metering		
Peak	8.1	40
Off-Peak	4.2	---
C - LV Customers		
Predominantly Off-peak Users	5.5	
Residential Users	9.7	

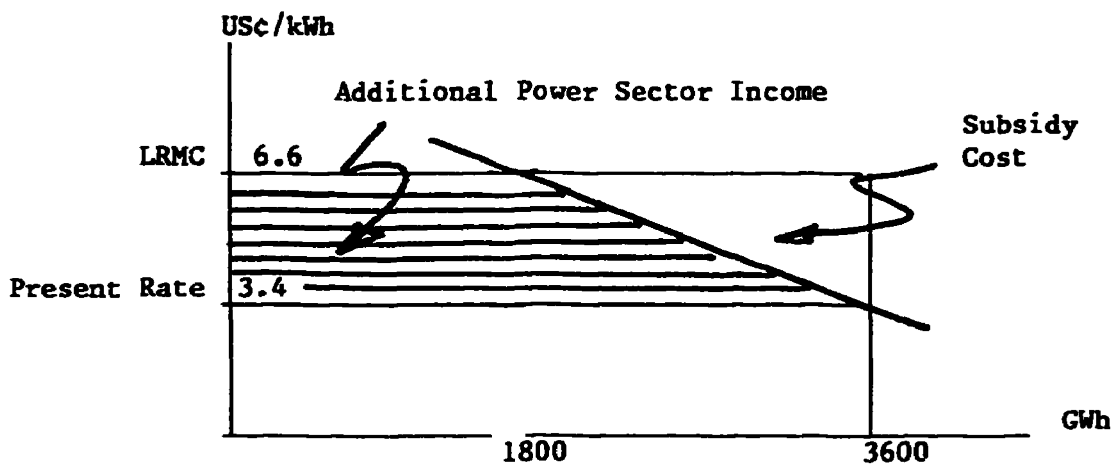
5. If the reference rates are compared to present tariffs, the fast straight forward change that could be implemented consists of offering a rate based on time of day metering, together with a difference according to voltage level deliveries; this would apply mainly to industrial users and would provide incentives for better energy use. For low voltage consumers, block structures do not reflect marginal costs and should be eliminated except, possibly, for a first block that could benefit very low income users.

6. Tariff level readjustments - a comparison of the typical average bills with the reference tariffs is summarized in the following table:

	Present USc/kWh	Reference USc/kWh	Adjustment (%)
Large Industrial	3.7	5.7	+ 54
Low Voltage:			
Industrial	3.2	5.7-9.7	+ 72 to + 200
Commercial	4.0	5.5-9.7	+ 38 to + 140
Residential (200 kWh)	3.6	9.7	+ 170
Residential (60 kWh)	1.1	9.7	+ 780

High Voltage INECEL Subsidiaries: The capacity charge would need an increase of 300%, the off-peak energy charge would have to be increased 80% and the peak energy charge would need a 300% adjustment.

7. Income Effects: If tariffs are readjusted to the marginal cost level, consumption can be expected to decrease and the power sector's revenue can be expected to increase. The present overall rate of 3.4 USc/kWh would have to be increased around 100% in order to reach the marginal cost level. Present consumption is on the order of 3600 GWh/year; assuming a price-elasticity of 0.5, demand would be reduced by 50% in the long run, i.e. it would decrease by 1800 GWh. The situation is shown in the following diagram:



The welfare gain of having marginal cost tariffs at present would be US$29 million/year (i.e. the subsidy cost) and the additional power sector income would be about US$ 86 million/year (59% of power sector revenues in 1984.)

ENERGY CONSERVATION AND SUBSTITUTION IN THE TRANSPORT SECTOR

ENERGY CONSUMPTION SCENARIOS FOR ROAD TRANSPORT
MILLION GALL. OF FUEL

Road Transport Mode	Scenarios for 2000				
	High Consumption	Low Consumption	Fuel	Savings (%)	Share of Savings (%)
Light vehicles	312	279	33	11	13
Taxis	92	78	14	15	6
Urban Buses	111	65	46	41	18
Inter-Urban Buses	148	95	53	36	21
Freight Transport a/	337	229	108	32	42
Total	1,000	746	254	25	100

a/ Includes pipeline transport.

Source: INE.

INVESTMENT REQUIRED TO IMPLEMENT THE LOW CONSUMPTION SCENARIO FOR THE COMMERCIAL FLEET THROUGH THE YEAR 2000

Road Transport Mode	Vehicle Fleet 1981	Vehicle Fleet 2000	Unit Investment (thousand US$)	Total Investment, Million US$ Replacement a/	Total Investment, Million US$ Incremental	Total Investment, Million US$ Total b/
Taxis	17,000	42,000	7	120	170	290
Urban Buses	3,200	7,070	90	290	350	640
Inter-Urban Buses	9,400	15,700	100	940	630	1,570
Freight Transport	41,700	41,830	40	1,230	440 c/	1,670
Total	71,320	106,600	---	2,580	1,590	4,170

a/ Based on 1981 vehicle fleet, except for freight transport.
b/ Based on 2000 vehicle fleet.
c/ Refers to additional capacity relative to 1981.

Source: INE.

IMPROVEMENTS INCORPORATED INTO VEHICLE FLEET UNDER
THE TWO SCENARIOS FOR THE YEAR 2000

Road Transport Mode Reference Case	1981	Scenarios for 2000 High Consumption	Change Over (%)	Low Consumption	Change Over (%)
Light Vehicles					
mileage, km/gal	31.3	34.4	9.9	38.6	23.3
Urban Buses					
mileage, km/gal	5.9	6.4	8.5	7.07	19.8
seats/vehicle	38.8	38.8	0.0	60.0	54.6
gal/100 km/seat	0.44	0.40	9.1	0.24	45.5
Inter-Urban Buses					
mileage, km/gal	14.0	15.1	7.9	15.5	10 7
seats/vehicle	26.4	26.4	0.0	40.0	51.5
gal/100 km/seat	0.27	0.25	7.4	0.16	40.7
Freight Transport					
mileage, km/gal	12.1	12.4	2.5	12.3	1.2
net cargo, ton	7.4	7.7	4.1	10.0	35.1
gal/100 km/ton	1.12	1.05	6.3	0.82	26.8

Source: INE.

Annex 6

ECUADOR
PREDICTION OF FUTURE OIL PRODUCTION BY FIELD
(All Producing Rates are Avg. Bbls. per Producing Day
Based on 350 Producing Days per Year)

Field Name	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	Cumul. Prod. 10 Year Per. MM bbls.
CEPE-Texaco Consortium											
Shushufindi-											
Aguarico	110000	110000	110000	110000	110000	110000	110000	110000	110000	110000	385.000
Sacha	61400	60000	60000	60000	60000	60000	60000	60000	60000	60000	210.490
Lago Agrio	11425	10200	9100	8100	7150	6350	5630	5000	4440	3945	24.969
Auca-Auca Sur	17450	16100	14455	12958	11610	10400	9520	8550	7440	6630	40.150
Atacapi	4100	3260	2640	2145	1743	1416	1150	935	760	620	6.569
Parahuacu	2300	1925	1612	1349	1129	945	791	663	555	465	4.107
Yuca-Yuca Sur	4650	4100	3750	3400	3100	2830	2570	2350	2140	1950	10.794
Yulebra	1500	1100	816	600	440	330	240	180	130	95	1.901
Culebra	1000	610	470	360	275	210	160	120	100	85	1.187
Cononaco	17038	15300	13773	12397	11158	10044	9040	8137	7324	6590	38.780
Rumiyacu	300	390	310	240	190	150	120	90	90	80	.686
Durano	700	600	560	620	490	450	430	400	370	350	1.705
Subtotal CEPE-Texaco	231863	223585	217486	212069	207285	203125	199451	196225	193549	190810	726.337
CEPE-City Consortium											
Mariann	1380	1290	1200	1120	1050	980	900	850	790	735	3.603
Fanny 18-B	3030	2450	2000	1630	1330	1100	900	720	590	490	4.984
Tarapoa	330	270	220	170	140	110	90	80	60	50	.532
Joan											
Subtotal CEPE-City	4740	4010	3420	2920	2520	2190	1890	1650	1440	1275	9.119
CEPE											
Bermejo Sur	2000	7000	7000	6460	5960	5500	5100	4690	4330	4000	18.214
Charapa	800	70	680	650	630	610	590	570	550	530	1.988
Cuyabeno	6000	8000	7000	6000	5300	4600	4000	3500	2600	!7.500	
Sansahuari	3000	200	2800	2400	2000	1600	1200	1000	800	650	5.478
Secoya-Shushuqui	15900	16200	14340	12690	11230	9940	8800	7790	6890	6090	38.455
Shuara	7000	7600	6760	6000	5340	4750	4220	3760	3340	2970	18.109
Pichincha	1200	3200	3200	3170	2930	2720	2510	2330	2150	1980	8.887
Tetete	2000	4000	4000	3600	3200	2800	2400	2000	1700	1450	9.503
Bermejo Norte			3000	3000	2600	2200	1800	1400	1000	800	5.530
Capiron				2000	2000	1570	1230	970	770	500	3.106
Shiripuno				3500	3500	2980	240	2160	:800	1500	5.488
Tivacuno				4000	4000	3500	3060	2700	2300	1960	7.532
Tiguino				3500	3500	3060	2700	2300	2000	1740	6.580
Carabobo		3500	3500	3500	3200	2900	2700	2500	2300	2120	9.177
Pacayacu		600	600	500	400	300	200	100	100	80	1.008
Peninsula	1200	1180	1090	1000	920	850	780	720	680	650	3.175
Subtotal CEPE	39100	51550	53970	61970	56710	49880	41530	38490	33710	29710	159.817
Grand-Total- All Fields	275703	279145	274876	276959	266515	255195	242871	236365	228499	221795	895.273

Source: (1985-1993) DNH
(1994) Mission Estimate

CEPE's 1985 INVESTMENT PROGRAM - EXPLORATION AND PRODUCTION

EXPLORATION	US$
Geological studies - (oriente, Manabi, on-shore Santa Elena, offshore Progreso & Isla Puna..	309,380
Payments pending from previous years	75,000
Geochemical prospecting - (Oriente & Manabi) plus laboratory equipment for analyses........	686,440
Preparation for drilling one (1) well Progreso, including camp equipment............	56,000
Payments pending from previous years.....	300,000
Seismic work - (Amazon Region) Yasuni/Lorocachi 500 km.; Conambo Norte 800 km; Atacapi/Este Libertador 400 km; Pungarayacu 100 km; reprocess Conambo/Bobonaza 400 km; reprocess Bermejo 250 km.	14,266,310
Seismic work - (Coastal & Offshore Region) - Flavio Alfaro/Monterrey 500 km; Cuenca Progreso 500 km. cont'd; reprocess and interpret Isla Puna and Golfo de Guayaquil....................	4,188,030
Payments pending from previous years......	456,650
Pungarayacu (heavy oil) - drill 6 shallow wells and analyze reservoir rocks and fluids.........	599,265
Contract studies - Santa Elena Peninsula	690,000
Drill 1 exploration well - (Oriente) - Tapi 1..	977,250
Payments pending drilling '82, '83, & '84..	9,018,500
CEPE's portion (65%) of CEPE-Texaco exploration, including drilling one (1) exploration well...........................	1,400,120
CEPE's portion (21%) of CEPE-City exploration work	31,210
Total 1985 CEPE exploration investments	$23,204,005
Exploration payments pending from previous years.................................	$ 9,850,150

DEVELOPMENT	US$
Libertador Field	
Drill 6 development wells	3,912,000
Roads and well location	650,000
Drilling services and well equipment	12,445,200
Flow station, flowlines, electrical system, transfer station installation	9,000,000
Bermejo Norte Field	
Roads and well locations	600,000
Separators, manifolds, tubing	1,170,000
Road to Bermejo Sur	1,500,000
Cuyabeno Field	
Drill 3 development wells	1,953,200
Drilling services and well equipment	1,170,000
Road to Bermejo Sur	1,500,000
Tetete Field	
Drill 3 development wells	2,410,000
Drilling services and well equipment	7,666,800
Flowlines	2,250,000
Tiquino Field	
Roads and locations	200,000
Separators, manifolds, tubing, materials	930,00
Road to Cononaco	1,500,000
Sansahuari Field	
Flowlines	1,300,000
Road to Cantagallo	700,000
Bermejo Sur Field	
Art. lift equipment, flowlines, flow station, high pressure tubing	4,300,000
Guarumo Camp	
Warehouse and geological storage	65,000
Laboratory and data bank services	121,500
Guayaquil Operational Base - Posorja	
For logistical support of drilling	200,000
CEPE-Texaco (CEPE 65%)	
Drill 9 development wells	3,200,760
Plant and other equipment requirements	12,796,240
Miscellaneous	3,478,200
Transecuatoriano pipeline	1,075,080
CEPE-CITY (CEPE 21%)	
General exploitation	27,140
Total CEPE 1985 development investments	$82,994,620
Remaining payments due from 1984 investments	$ 530,000

Source: CEPE.

Annex 8

INVESTMENTS IN OIL FIELDS DEVELOPMENTS, 1985-1990
(Million 1984 US$)

	1985	1986	1987	1988	1989	1990
			Maximum Level			
CEPE	134.2	146.8	106.9	96.4	82.8	76.0
TEXACO	19.4	13.8	10.3	8.5	7.0	6.2
CEPE-City	3.2	1.4	1.5	0.6	0.7	0.7
Total	156.8	162.8	118.7	105.5	90.5	82.9
			Intermediate Level			
CEPE	113.7	124.7	88.1	73.7	59.9	56.5
TEXACO	16.8	10.7	8.7	7.7	6.5	5.8
CEPE-City	3.3	1.4	1.5	0.6	0.7	0.7
Total	133.8	136.8	98.3	82.0	67.1	63.0
			Minimum Level			
CEPE	49.0	35.3	38.7	29.1	23.3	21.0
TEXACO	10.8	7.6	7.0	6.3	4.8	4.4
CEPE-City	3.3	1.4	1.5	0.6	0.7	0.7
Total	63.1	44.3	47.2	36.0	28.8	26.1

PETROLEUM PRODUCTION AS A FUNCTION OF INVESTMENT LEVELS, 1985-1990
(Million bbls per year)

	1985	1986	1987	1988	1989	1990
			Maximum Production a/			
CEPE	27.2	32.9	44.7	48.9	54.9	59.2
TEXACO	84.1	87.0	86.7	84.5	82.5	81.3
CEPE-City	1.0	0.9	0.8	0.6	0.6	0.5
Total	112.3	120.8	132.2	134.0	138.3	141.0
			Intermediate Production b/			
CEPE	22.4	25.6	34.9	38.0	43.0	44.3
TEXACO	80.9	81.3	80.9	78.8	76.9	74.5
CEPE-City	1.0	0.9	0.8	0.6	0.6	0.5
Total	104.3	107.[illegible]	116.6	117.4	120.5	119.3
			Minimum Production c/			
CEPE	18.6	18.5	20.3	18.9	17.1	15.5
TEXACO	77.0	75.5	73.4	70.3	67.0	64.2
CEPE-City	1.0	0.9	0.8	0.6	0.6	0.5
Total	96.6	94.9	94.5	89.9	84.7	80.2

a/ Production level associated with maximum investment level.
b/ Production level associated with intermediate investment level.
c/ Production level associated with minimum investment level.

Source: World Bank.

Annex 9

GULF OF GUAYAQUIL - AMISTAD
NON-ASSOCIATED GAS RESERVE ESTIMATES

Source	Date	Recovery Factor (%)	Reserves in BCF Proven	Probable	Possible	Total
CEPE	Sept 1975	81.3	350.1	558.0	-	908.1
CEPE	Dec 1975	81	259.8	1914.6	1676.4	3850.8
DEGOLYER & McNAUGHTON	May 1976	77	296.0	290.0	340.0	926.0
CEPE	Apr 1977	78	237.0	203.0	396.0	836.0
CEPE	Jul 1981	70	202.4	93.7	-	296.1
BRASPETRO-PETROFERTIL	May 1984	80	281.8	87.5	72.1	440.7

GULF OF GUAYAQUIL ECONOMIC ANALYSIS

GUAYAQUIL GAS PROJECT INVESTMENT BREAKDOWN

Investment Item	Project Packages capital cost	I, II, III, operating cost	Project Package IV Capital Cost million US$
Exploration drilling	34.6	-	34.5
Production drilling	42.5	-	42.5
Completions	15.9	-	15.9
Platforms	78.7	1.05	78.8
Offshore pipelines	36.8	1.10	41.4
Onshore pipelines	22.2	0.37	14.7
Total	230.7	2.52	227.8

Source: CEPE and Mission estimates.

GAS NETBACK AND NPV OF GAS SUBSTITUTION FOR DIESEL OIL FOR POWER GENERATION IN THE GUAYAQUIL AREA

Discount Rate (% per year)	Gas Netback Value (US$/MMBTU)			NPV (million US$)		
	Project Lifetime, years					
	5	10	15	5	10	15
	Retrofit Investment: US$9.6 million					
10	6.36	6.42	6.43	144.36	240.25	299.79
15	6.33	6.39	6.41	126.25	194.14	227.90
20	6.31	6.37	6.38	111.28	160.24	179.92
	Retrofit Investment: US$19.2 million					
10	6.21	6.32	6.36	134.28	230.17	289.71
15	6.16	6.27	6.31	115.93	183.82	217.58
20	6.11	6.22	6.25	100.72	149.68	169.36

Basis:
- 192 MW of diesel and gas turbine retrofitted for gas burning, at 0.9 load factor
- 48,100 MMBTU/D of gas consumption
- Diesel oil replacement value of gas: US$6.51/MMBTU
- Economic price of gas: US$4.19/MMBTU

Source: Mission estimates.

GAS NETBACK AND NPV OF GAS AS AN INDUSTRIAL FUEL IN THE GUAYAQUIL AREA

Discount Rate	Gas Netback Value			NPV		
(% per year)	(US$/MMBTU)			(million US$)		
	Project lifetime, years					
	5	10	15	5	10	15
10	4.96	5.02	5.04	42.96	74.60	94.24
15	4.94	5.00	5.02	37.04	59.44	70.60
20	4.92	4.98	4.99	32.20	48.36	54.84

Basis:
- Retrofit investment: US$8 million.
- Gas consumption: 40 MMSCFD.
- Replacement value of gas for combination of fuels replaced: US$5.11/MMBTU.
- Economic price of gas: US$4.19/MMBTU.

Source: Mission estimates.

ASSUMPTIONS UNDERLYING ECONOMIC ANALYSIS FOR THE AMMONIA/UREA OPTION OF GAS UTILIZATION

A. General

1. Plant Configuration: 1,000 tpd ammonia and 1,650 tpd urea plants
2. Designed Capacity: 544,500 tonnes of urea per year (330 days)
3. Capacity Utilization: 60% and 80% for the first and second years, and 90% thereafter
4. Economic Life: 15 years

B. Costs

1. Capital Costs: US$320 million, or US$588/annual ton capacity
2. Gas Consumption and Price: 320 MMBTU/ton of urea at fuel oil equivalent value - fuel oil equivalent value is derived from projected fuel oil prices based on EPD petroleum price projections as follows:

	1985	1990	1995
Crude ($/bbl)	28.60	23.80	28.80
Fuel Oil Price/Crude Price	0.67	0.71	0.77
Fuel Oil Equivalent Value of Gas in Ecuador (US$/MMBTU)	4.19	3.70	4.85

3. Other Variable Cost: US$18/ton of urea

C. Urea Price

1. Projected Prices: Feature urea price is projected by the World Bank Economic Analysis and Projection Department.
2. Sales: Local demand is assumed to grow at 4.8% p.a., and surplus production is assumed to be exported.
3. Economic Benefits: Local consumption is value at CIF prices, and exports are valued at FOB prices.

	1985	1990	1995
FOB (US$/ton)	175	224	224
CIF Ecuador (")	198	247	267

AMMONIA/UREA PRODUCTION OPTION FOR GAS UTILIZATION

Economic cost and Benefit Streams

Year	Capital Cost	Working Capital	Natural Gas	Other Variable Cost	Fixed Cost	Benefits: Import a/ Substitution	Benefits: Exports	Net Benefit Flow
1	(32.0)							(32.0)
2	(96.0)							(96.0)
3	(112.0)							(112.0)
4	(80.0)	(5.0)						(85.0)
5			38.7	5.9	27.5	49.2	28.7	5.8
6			54.5	7.8	27.5	47.6	51.9	9.7
7			64.6	8.8	27.5	55.5	63.1	17.7
8			68.2	8.8	27.5	60.2	61.7	17.4
9			72.0	8.8	27.5	63.1	60.1	14.9
10			76.0	8.8	27.5	67.1	58.2	13.0
11			76.0	8.8	27.5	70.3	55.4	13.4
12			76.0	8.8	27.5	73.6	52.5	13.8
13			76.0	8.8	27.5	77.2	49.7	14.6
14			76.0	8.8	27.5	80.8	46.8	15.3
15			76.0	8.8	27.5	84.7	43.9	16.3
16			76.0	8.8	27.5	88.8	41.1	17.6
17			76.0	8.8	27.5	93.0	38.2	18.9
18			76.0	8.8	27.5	97.4	35.4	20.5
19		(5.0)	76.0	8.8	27.5	102.1	32.5	27.3

Net Present Value: -US$193.7 million @ discount rate of 10%
-US$203.0 million @ discount rate of 20%

Gas Netback: +US$0.83/MMBTU @ discount rate of 10%
-US$0.14/MMBTU @ discount rate of 20%

a/ Local demand for nitrogen fertilizer is assumed to grow at 4.8% p.a.

ORIENTE ECONOMIC ANALYSIS

GAS NETBACK AND NPV OF PROJECTS TO SUBSTITUTE GAS FOR DIESEL OIL FOR POWER GENERATION IN THE ORIENTE

Discount Rate (% per year)	Gas Netback Value (US$/MMBTU)	NPV (million US$)
	Retrofit Investment: US$2 million	
10	6.34	64.93
15	6.28	49.46
20	6.23	39.14
	Retrofit Investment: US$4 million	
10	6.17	62.93
15	6.07	47.46
20	5.97	37.14

Basis:
- 40 MW Diesel generation retrofitted for gas burning at typical load factor of Lago Agrio retrofit project.
- 4,384 MMBTU/D of gas consumption.
- Diesel oil replacement value of gas equal to US$6.51/MMBTU.
- Economic price of gas equal to US$1.00/MMBTU.

Source: Mission estimates.

LIBERTADOR PROJECT INVESTMENT BREAKDOWN

Investment Item	Capital Cost (thousand US$)	Percent
1. Equipment		
- two low pressure gas compressors	600	7.7
- one condensable recovery unit for Secoya	2,500	32.3
- one pumping unit	300	3.9
Subtotal	3,400	43.9
2. Pipeline		
- 38.5 km of 3-in pipe at US$100,000/km	3,850	49.7
3. Other		
- retrofit at Aguarico	31	0.4
- bridge over Aguarico river	462	6.0
Subtotal	493	6.4
Total	7,743	100.0

Source: CEPE.

GAS NETBACK AND NPV OF INDUSTRIAL UTILIZATION
OF GAS IN PETROLEUM OPERATIONS IN THE ORIENTE

Discount Rate (% per year)	Gas Netback value (US$/MMBTU)	NPV (thousand US$)
Sacha:	Retrofitting seven power oil prime movers from diesel oil to natural gas US$80 thousand investment 23×10^3 MMBTU per year	
10	6.05	883.9
15	5.92	661.0
20	5.77	512.5
Auca:	Retrofitting eight power oil prime movers from crude oil to natural gas US$250 thousand investment 79×10^3 per year	
10	4.30	1,985.3
15	4.16	1,468.4
20	4.04	1,124.0
Lagro Agrio:	Retrofitting one 3 MW and two 1 MW turbo generators from diesel oil to natural gas US$250 thousand investment 200×10^3 MMBTU per year	
10	6.35	8,131.9
15	6.30	6,193.8
20	6.24	4,902.4

Basis:
- Diesel Oil replacement value of gas: US$6.51/MMBTU
- Crude Oil replacement value of gas: US$4.72/MMBTU
- Economic price of gas: US$1.00/MMBTU

Source: CEPE-TEXACO and mission estimates.

POWER DEMAND PROJECTIONS

1. Due to favorable economic circumstances, electricity demand in Ecuador gew at very high rates until recently: 72% per year in 1970-75 and 17% per year during 1975-80.

2. Recent years have been affected by an economics recession: as of 1983, load growth had decelerated to 7% and preliminary data for 1984 show a growth of only 2%.

3. For forecasting purposes, INECEL has therefore adopted an econometric model that relates consumption of electricity to GDP. The model can be considered somewhat crude, specially because it does not involve sectoral differences not tariff policies. The resulting forecasts are summarized in table below.

4. Qualifying these estimates is difficult due to:

(a) recent trends that tend to overwhelm perceptions of future growth;

(b) uncertainty related to the unserved population and its consequent market potential;

(c) uncertainty with respect to demand in regions that will shortly be connected to the central grid and have had generation constraints in the past; and

(d) weakness in the sector's finances that could prevent INECEL's subsidiaries from extending service as much as they could.

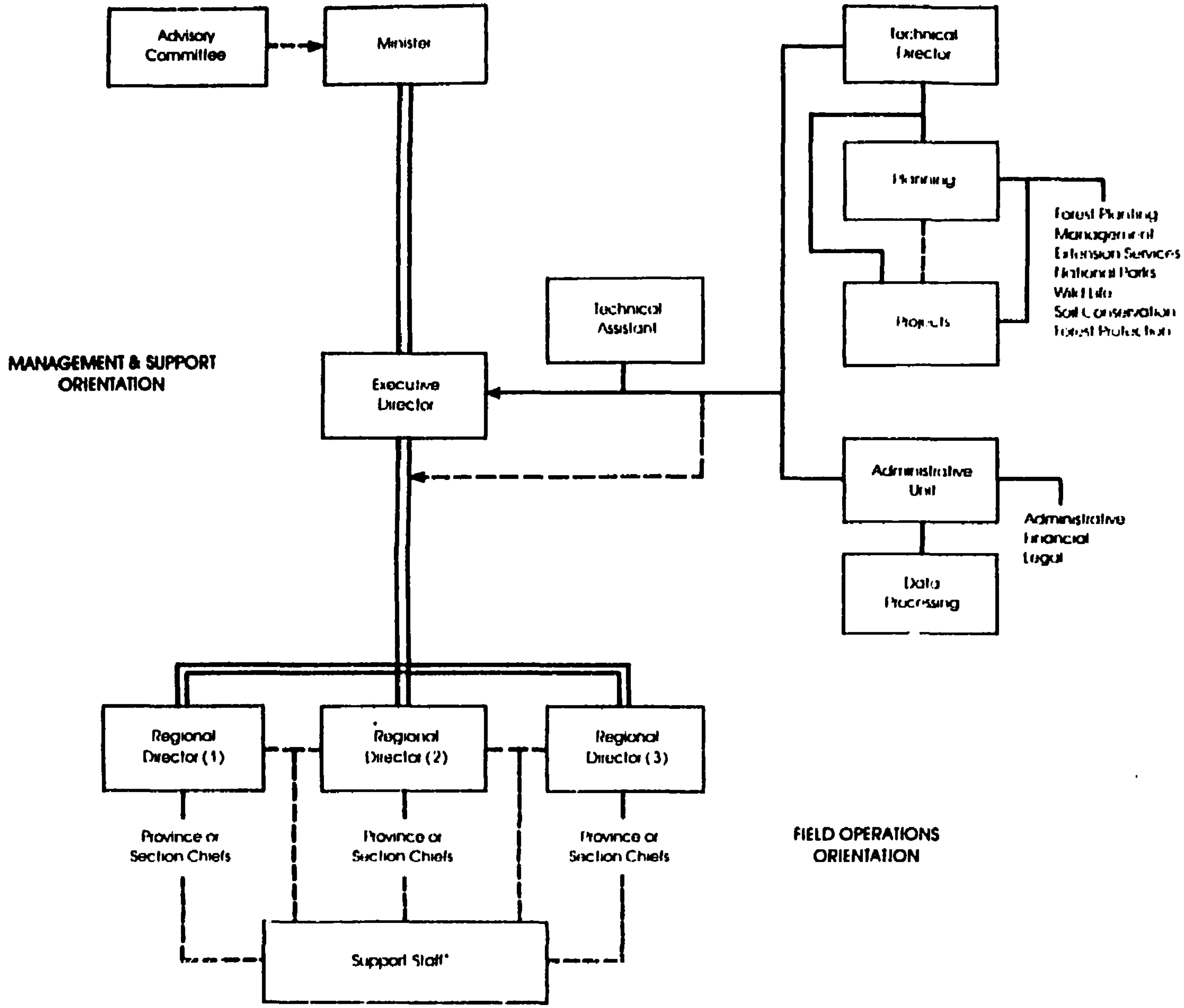
5. INECEL's forecasts show yearly growth rates between 6% and 7% for 1984-1995. These figures appear somewhat conservative given the demand potential of the country. However, considering recent trends and the sector's constraints, they would appear to be appropriate for planning purposes.

FORECASTS FOR PUBLIC SECTOR DEMAND

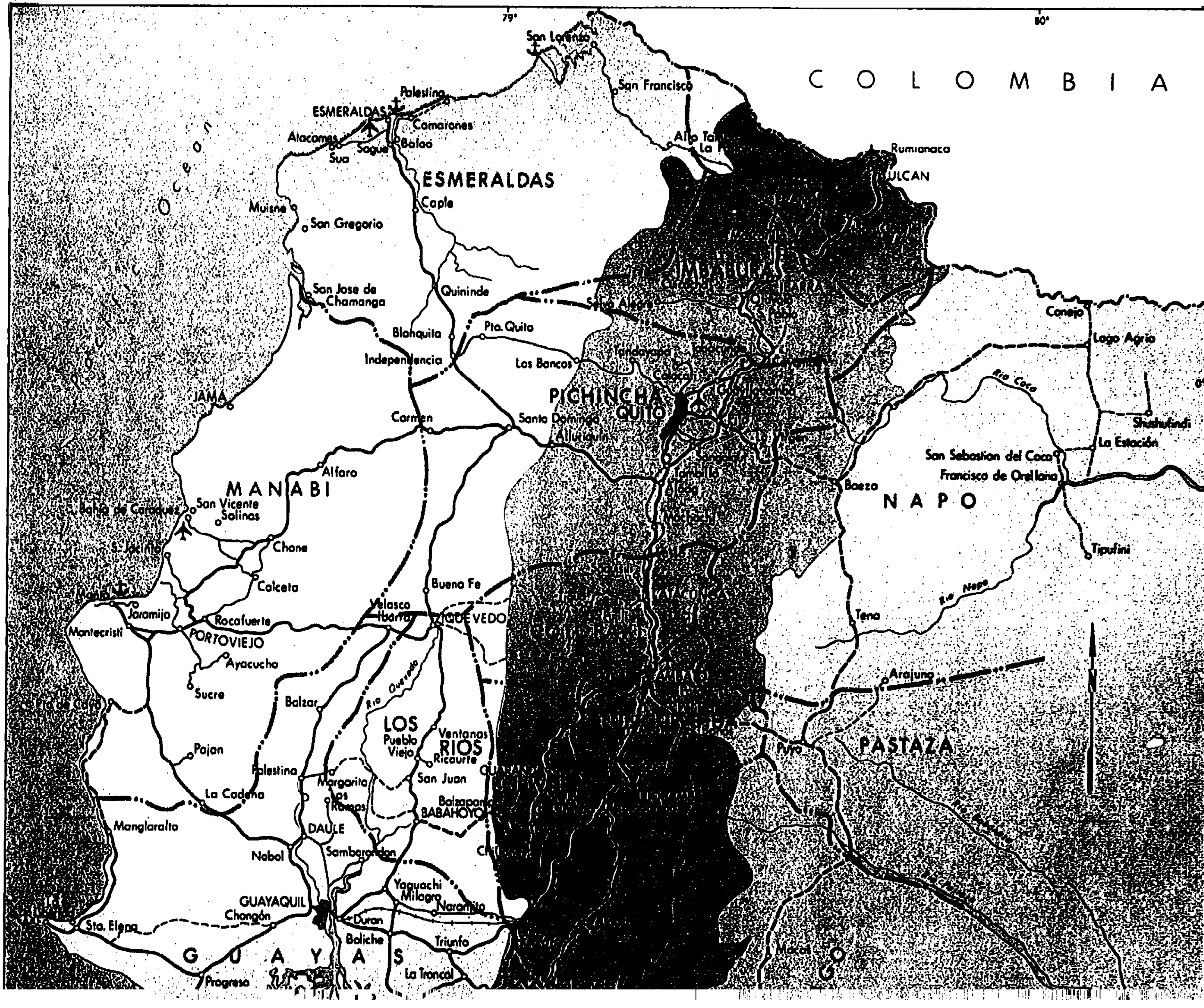
Year	Consumption (GWh)	Production (GWh)	Demand (MW)
1985	3780	4470	860
1986	4000	4720	910
1987	4250	4580	970
1988	4500	5260	1040
1989	4800	5590	1110
1990	5110	5930	1180
1991	5430	6280	1260
1992	5790	6660	1330
1993	6200	7100	1410
1994	6630	7570	1500
1995	7140	8110	1610
1996	7710	8760	1730
1997	8360	9490	1870
1998	9060	10300	2020
1999	9860	11200	2190
2000	10740	12210	2380
2001	11720	13320	2600
2002	12790	14530	2820
2003	14050	15970	3100
2004	15150	17210	3330
2005	16450	18690	3600

Source: Inecel

Recommended Organization for PRONAF



*Field support staff distributed according to priority established by [illegible] for ongoing programs



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San Gregorio
San Jose de Chamanga
Quininde
Blanquita
Pto. Quito
Independencia
Los Bancos
PICHINCHA
QUITO
JAMA
Carmen
Santo Domingo
Alluriquin
Alfaro
M A N A B I
San Vicente
Salinas
Bahia de Caraquez
Chone
Calceta
Buena Fe
Velasco Ibarra
QUEVEDO
Jaramijo
Rocafuerte
Montecristi
PORTOVIEJO
Ayacucho
Sucre
Balzar
LOS RIOS
Ventanas
Pueblo Viejo
Ricaurte
Pajan
Palestina
Margarita
San Juan
La Cadena
Balzapamba
BABAHOYO
Manglaralto
DAULE
Nobol
Samborondon
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Naranjito
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Duran
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G U A Y A S
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Progreso
Conejo
Lago Agrio
Rio Coca
Shushufindi
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Puyo
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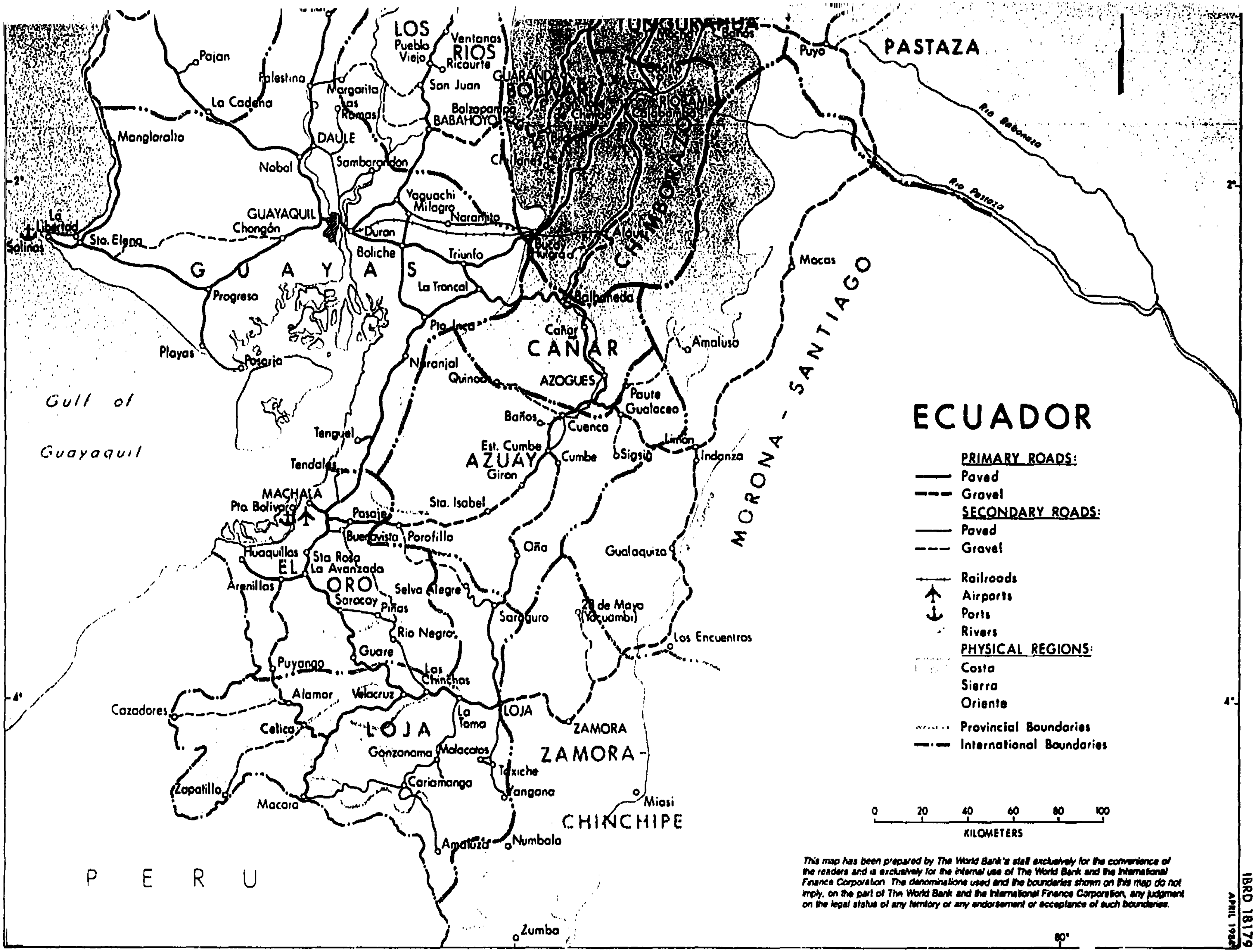
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Ports
Rivers
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Costa
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International Boundaries
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KILOMETERS
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PASTAZA
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GUAYAS
CAÑAR
AZUAY
EL ORO
LOJA
ZAMORA - CHINCHIPE
MORONA - SANTIAGO
PERU
Gulf of Guayaquil
Rio Bobonaza
Rio Pastaza
Puyo
Pajan
Palestina
La Cadena
Manglaralto
Nobol
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Samborondon
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Ricaurte
San Juan
Balzapamba
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La Libertad
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La Troncal
Progreso
Playas
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Piñas
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Saraguro
Rio Negro
Los Encuentros
Puyango
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Las Chinchas
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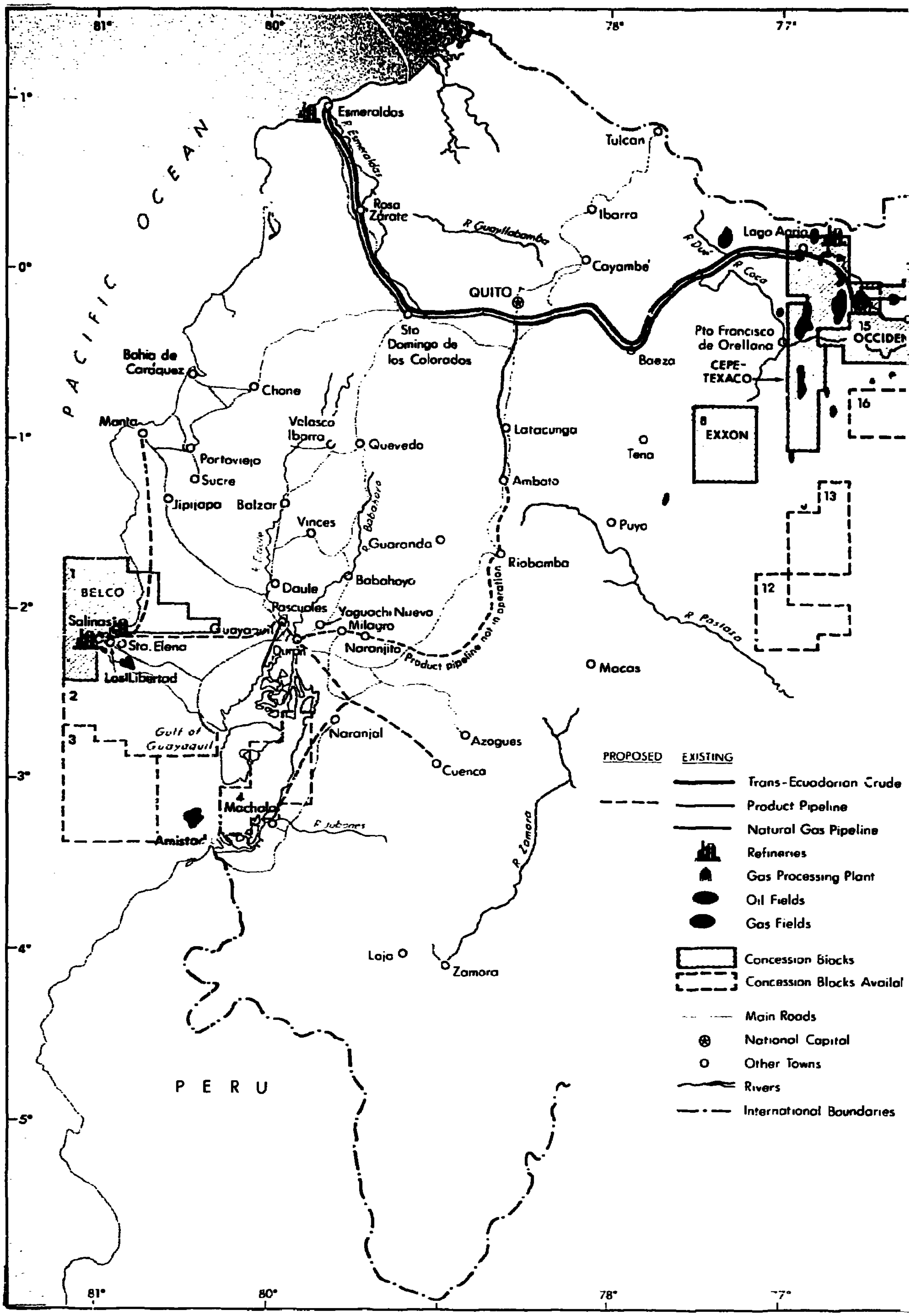

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QUITO
Sto Domingo de los Colorados
Baeza
Pto Francisco de Orellana
15 OCCIDE
CEPE-TEXACO
16
8 EXXON
Bahia de Caráquez
Chone
Manta
Portoviejo
Sucre
Jipijapa
Velasco Ibarra
Quevedo
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Ambato
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Guaranda
Riobamba
Babahoyo
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Salinas
Guayaquil
Yaguachi Nuevo
Milagro
Naranjito
Durán
Sto. Elena
La Libertad
Product pipeline not in operation
R. Pastaza
12
Macas
2
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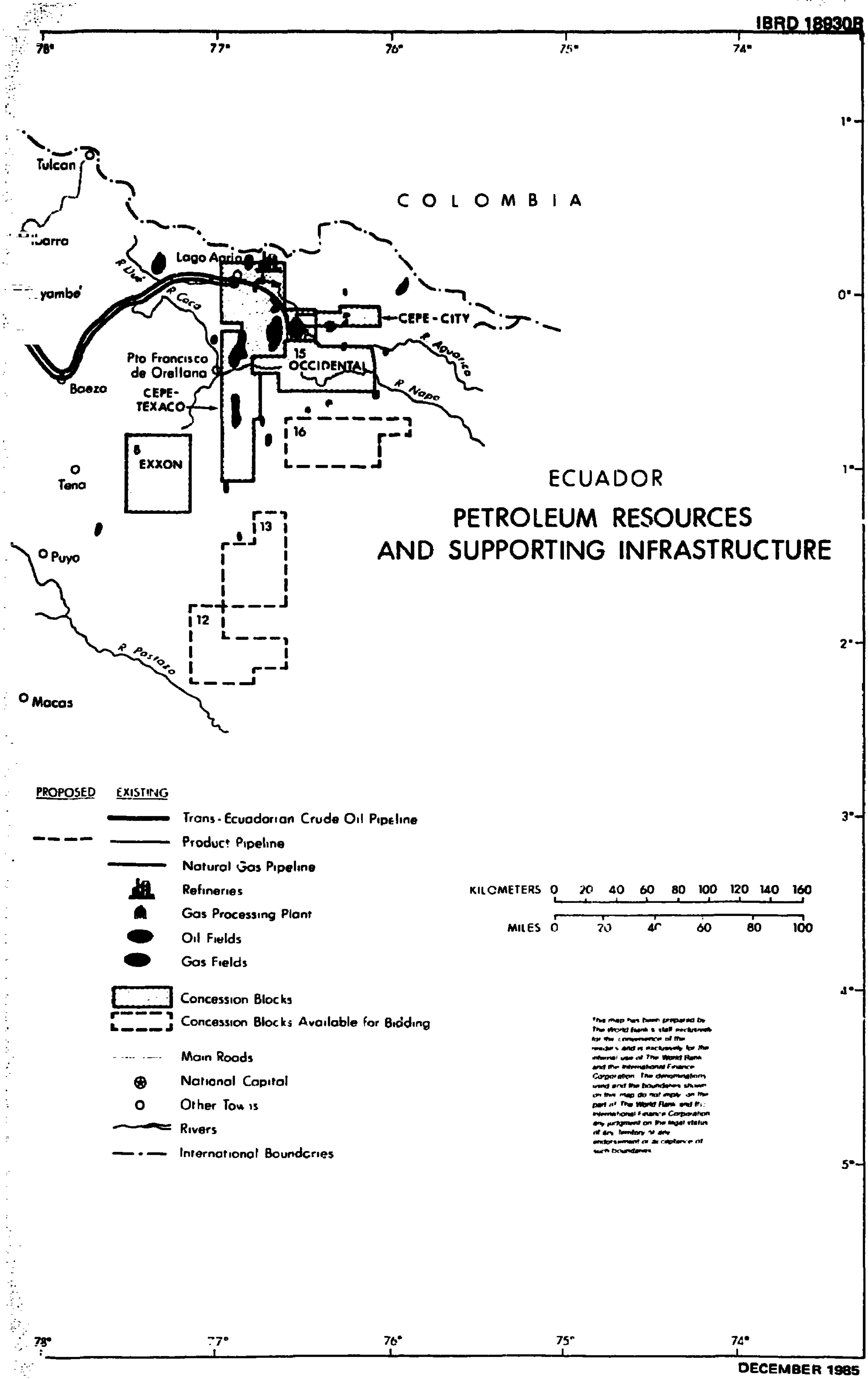
Gulf of Guayaquil
Naranjal
Azogues
Cuenca
4
Machala
Amistad
R. Jubones
R. Zamora
Loja
Zamora
PERU
PROPOSED
EXISTING
Trans-Ecuadorian Crude
Product Pipeline
Natural Gas Pipeline
Refineries
Gas Processing Plant
Oil Fields
Gas Fields
Concession Blocks
Concession Blocks Availal
Main Roads
National Capital
Other Towns
Rivers
International Boundaries



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R. Napo
Baeza
CEPE-TEXACO
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ECUADOR
PETROLEUM RESOURCES AND SUPPORTING INFRASTRUCTURE
13
Puyo
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R. Pastaza
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PROPOSED
EXISTING
Trans-Ecuadorian Crude Oil Pipeline
Product Pipeline
Natural Gas Pipeline
Refineries
Gas Processing Plant
Oil Fields
Gas Fields
Concession Blocks
Concession Blocks Available for Bidding
Main Roads
National Capital
Other Towns
Rivers
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DECEMBER 1985

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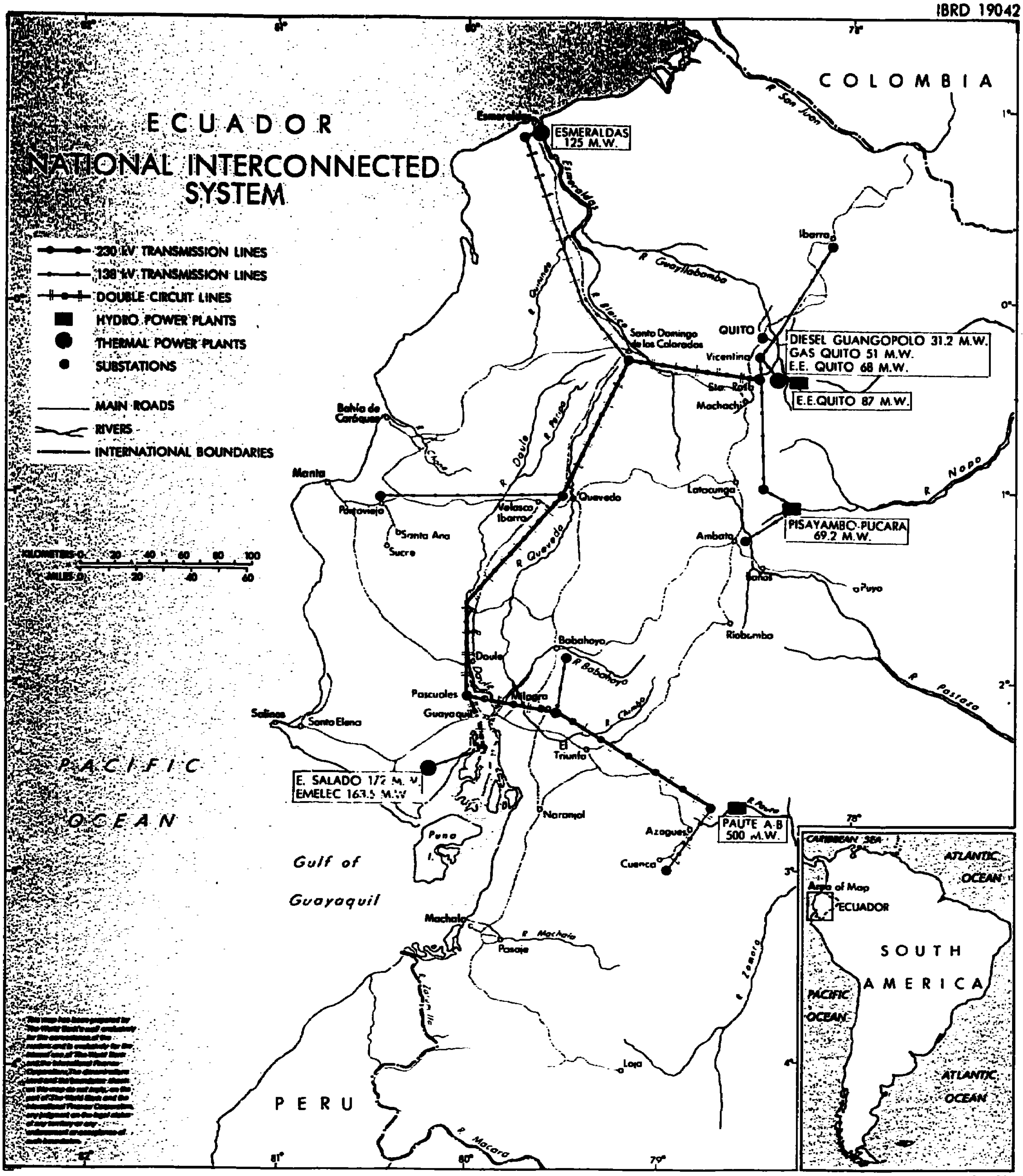
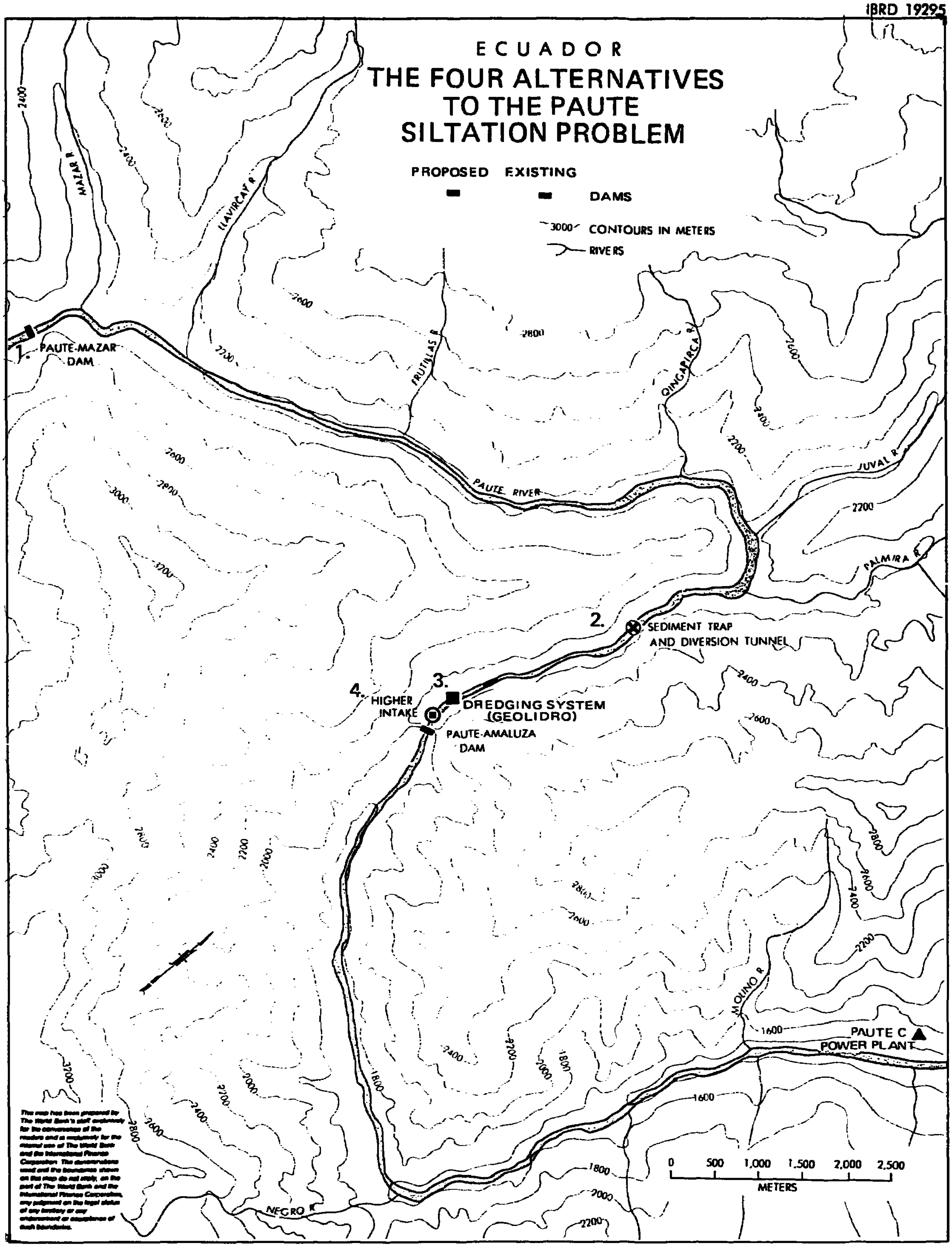


AUGUST 1985



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