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**Joint Peru/United States Report on
Peru/United States Cooperative
Energy Assessment**

Volume 4 of 4 Vols.
Annexes 8-11

MASTER

August 1979

U.S. Department of Energy
Assistant Secretary for International Affairs

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R&D AND PROGRAM MANAGEMENT

AN ASSESSMENT OF PERUVIAN
BIOFUEL RESOURCES AND ALTERNATIVES

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Prepared for
Developing Country Energy Program
Office of International Affairs
U.S. Department of Energy

1979

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AN ASSESSMENT OF PERUVIAN BIOFUEL RESOURCES AND ALTERNATIVES

by

Jerome P. Harper, Wayne Smith, and Eliseo Mariana

ABSTRACT

A comprehensive assessment of the biofuel potential of Peru is presented. Topics discussed cover current biofuel utilization practices; the evaluation of Peruvian biomass productivity; identification of Peruvian agricultural and forestry resources; an assessment of resource development and management concerns; an identification of market considerations; a description of biofuel technological options; and a regional identification of biofuel technology applications. The discussion of current biofuel utilization centers on a qualitative description of the main conversion approaches now being practiced in Peru. Biomass productivity is evaluated in the context of the terrain, soil, and climatic conditions found in Peru. A quantitative description of the energy potential which could be realized from agricultural and forestry resources of Peru follows. A regional picture is given for the production of agricultural residues and forest resources that could potentially supply energy. The assessment of resource development and management concerns focuses on harvesting, reforestation, training, and the environmental consequences of utilization of forest resources. Market factors assessed include: importation, internal market development, external market development, energy policy and pricing, and transportation. Ten biofuel technology options for Peru were identified: small to medium scale gasification, a wood waste inventory, stationary and mobile charcoal production systems, wood distillation, forest resource development and management, electrical cogeneration, anaerobic digestion technology, development of ethanol production capabilities, and agricultural strategies for fuel production. Based upon these biofuel options, nine applications were identified for the Costa Region, eight applications were identified for the Sierra Region, and ten applications were identified for the Selva Region.

I. INTRODUCTION

PURPOSE

In response to the hardships placed on developing countries by soaring energy prices, the United States Government has initiated a program to assist these countries to fully develop their energy resources. Between May and September, 1978, the United States government in cooperation with the Peruvian government undertook a cooperative study to assess the opportunities for energy development in Peru. The purpose of this study, which was organized by the U.S. Department of Energy, was to quantify the energy resources available throughout the country, to evaluate the present and future energy supply/demand situation, to identify alternative technological options for energy development, and to propose a comprehensive program for integrating energy development with overall national development.

The approach taken in this study was broad. Energy resources assessed included: oil and natural gas; coal; geothermal; uranium; hydropower; solar; wind; and biofuels. A comprehensive set of technological options for converting these resources into useful energy was identified and evaluated. This report describes the results of the Peruvian Energy Assessment provided by the members of the Biofuel Resources and Technology Team selected by the U.S. Department of Energy for the study.

SCOPE

A comprehensive picture of the potential for the utilization of nonconventional biofuels is given in this report. The assessment begins by identifying current utilization of biofuel resources in Peru. An evaluation is then made of the potential biomass productivity of Peru and the present supplies of biomass available from the country's agriculture, forest, and other resources. The demand situation for biomass is assessed in terms of competitive uses and market development. A discussion of the technological avenues, and resource development and management considerations for increased utilization of biofuels then follows. The assessment concludes by identifying a set of biofuel technology options for developing this energy resource in Peru, and by providing a regional appraisal of their applicability. The

regions discussed in the report are: the dry Costa Region; the mountainous Sierra Region; and the wet, tropical Selva Region (see Figure 1 for geographic location of these regions). The sites visited by the biofuel team members are identified in Figure 1. This method of analysis provides an evaluation of current supplies and production potential of biofuels, an assessment of the opportunities and consequences of biofuel development, and a description of promising biofuel options for Peru.

Figure 1. Location of Sites Visited in Peru in Relationship to Costa, Sierra, and Selva Regions

II. CURRENT STATUS OF BIOFUEL UTILIZATION

NATIONAL PLANS

The official document outlining plans for energy development in Peru (Plan Energetico Nacional, 1978) makes no specific mention of expanding the use of biofuels as an energy resource in the future. However, contacts with responsible individuals in several Peruvian ministries indicate a growing awareness of the importance of biofuels in the future development of energy resources in Peru. Such awareness is evident from the recent study undertaken by the Peruvian government and the United Nations to evaluate non-commercial fuel utilization in the country. Energy options discussed at meetings with persons from the Ministry of Energy and Mines focused on the pyrolysis of forestry wastes to produce combustible gases, oils, and charcoal; individuals from INDUPERU expressed interest in production of charcoal from biomass to use as a substitute for imported coke and in the direct combustion of biomass for electricity production; and Ministry of Agriculture personnel were very positive about developing forest plantations in the Sierra region of the country.

Interest in biofuel energy options is evident also in other sectors of Peruvian society. Research efforts at several universities are focused on increasing wood production. The industrial sector, especially those involved in the forest products or sugar processing industries are particularly interested in converting their processing wastes into an energy resource. Thus, much consideration is now being given in Peru to develop or utilize biomass energy resources, however, no formal national plan has been proposed and uncertainty exists concerning the best way to develop these resources.

AGRICULTURAL SOURCES

Of all the agricultural crops in Peru, only one to date is a significant factor in the energy situation in the country. This crop is sugarcane which produces bagasse for combustion, electricity, and process heat, and molasses for alcohol production.

These systems are very energy efficient since both electricity and steam are produced by these power facilities (i.e., co-generation) (Casa

Grande, 1978). Irrigation pumps are electrically driven using power converted by their own sugar mills. Presently they use about 90% bagasse and 10% oil to fire the boilers. The amount of oil will increase to 30% in the near-term due to increased use of bagasse by the paper industry (Casa Grande, 1978). The sugar industry now uses 160 million liters of oil annually.

Peru currently allocates sugarcane for either sugar, alcohol, or chancaca (molasses). In 1976, a production of 30,404,000 liters of alcohol from molasses was reported by the Alcohol and Beverages Department of the National Bank (Banco de la Nacion, 1977). This alcohol was not used directly for fuel, but was converted to ethylene which was then used for PVC production. Thus, the alcohol directly substitutes for a petroleum derived chemical feedstock.

COTTON-GIN WASTES

Another crop residue which is being used as an energy resource is cotton-gin waste. Stems, leaves, and other types of trash are left over from the ginning process. Systems in the U.S. have been developed for burning this waste to produce heat for drying cotton at the gins. A similar system was reported to be in operation near the town of Buenos Aires, Peru. The spread of these systems throughout would increase the energy self-sufficiency of the Peruvian cotton industry.

ANIMAL WASTE

Other major agricultural crops are not being extensively utilized because the distribution of these resources throughout the country is highly dispersed, affecting the supply logistics.

In the Peruvian highlands, dung has been used both as fuel and fertilizer since about 500 A.D. (Winterhalder et al., 1974). As a fuel, dung is utilized for cooking and heating in the highlands. The sources of dung are llama, alpaca, and cattle. The waste is collected and piled on fences or roofs or in open fields to be sun-dried (see Figure 2).

The Peruvian highlands are harsh climatic and topographic areas in which to grow trees. For this reason dung is used, particularly above the tree line, instead of firewood. The few stands of trees which exist in the

Figure 2: Dung Being Dried on a Fence and on the Ground, in the Sierra Region (Photo Courtesy of R. Giesecke, Member Peruvian Energy Assessment Team.)

Figure 3: Typical Sierra Farm with Eucalyptus Border Planted for Firewood (Photo Courtesy of R. Giesecke, Member Peruvian Energy Assessment Team.)

highlands are far from most households thus, wood collection requires great expenditure of time and effort (UNDP, 1978). Families prefer cattle dung because it is the easiest to collect and cattle dung fire is easy to kindle, maintain, and produces a hot fire with a minimum of smoke (Winterhalder et al., 1974).

Local population has obtained a flow of energy and nutrients from these high-altitude mountainous environments efficient enough to permit family subsistence. The amount of this type of energy available and its consumption are currently being investigated by a UNDP study group and will be reported at the end of 1978.

FOREST SOURCES

Firewood

Wood is an economical and one of the more extensively utilized sources of energy for cooking and heating in areas below the high-altitude mountainous environment. Wood collection generally is carried out by all members of the family. The UNDP study group has estimated that 20% of an adult's time is expended in wood collection. The children are instructed to pick-up little pieces of tree branches or twigs and any wood waste found during playing and to bring it home. Of all the wood used in Peru, 60-85% is used as firewood. Eucalyptus is one of the most used species for firewood in Peru.

The Eucalyptus is a prime candidate for firewood production and harvesting since many of these trees can reach a suitable size for harvesting in a few years. Furthermore, some Eucalyptus species have the ability to sprout (coppice) again from their stumps after harvesting; thereby, minimizing the requirements for extensive land clearing, cultivation, and replanting operations after each harvest (Mariani, 1978). Several Eucalyptus trees planted on a house perimeter can supply all the firewood required for a family for many years to come (see Fig. 3).

Charcoal

Charcoal is a favorite fuel for cooking and heating throughout Peru. Because of past deforestation in the Sierra region, laws were passed many

years ago prohibiting its production. However, charcoal is still produced in the Sierra and Selva regions, but its cost is prohibitively high for extensive utilization. It is used when available for cooking, particularly in restaurants.

A summary of current biofuel utilization practices in Peru is given in Table 1.

Table 1. Summary of Current Biofuel Usage in Peru

Biomass Resource	Conversion Technology	Biofuel Type	Energy Produced	Utilizing Sector
Wood	Direct combustion	Firewood	Process Heat	Cooking and heating (home and commercial)
Wood	Pyrolysis	Charcoal	Process Heat	Cooking (home and commercial) & heating
Sugarcane	Direct combustion	Bagasse	Process Heat, Steam and Electricity	Industrial and residential
Sugarcane	Fermentation	Molasses Bagasse	Alcohol	Industrial
Animal Waste	Direct Combustion	Dung	Process Heat	Cooking and heating (home)
Agricultural Residue	Direct Combustion	Cotton Gin Waste	Process Heat	Industrial

III. BIOFUEL PRODUCTIVITY -- LAND AND CLIMATE CONSIDERATIONS

Terrain

Peru possesses three distinct physiographic regions -- Costa, Sierra, and Selva -- each of which can be divided into subregions. The generalized regions are characterized as follows:

1. Costa: Sea level to Andean Mountain peaks represent the range of topography position in this region. Although some areas near the Pacific and certain inter-mountain valleys are level, much of this region is rugged. But most important, this area is mainly arid and productive only when irrigation water is available. Because of this, bioproduction has been limited to high value food crops under carefully managed irrigation. Productive capacity of these irrigated lands is great. Production in surplus of human needs occurs for certain crops (e.g., sugarcane). Agricultural residues and municipal wastes are the most promising biofuel resources in these areas.

In the Costa, about one million hectares are moist enough to support forests. These occur mainly in the region of Tumbes along the north coast.

2. Sierra: The central Andes comprise the Sierras. The topography varies from broad mountain valleys to the steep, barren, and snowcovered peaks of the Andes Mountains. Elevations in this region range from about 1,000 meters up to nearly 7,000 meters. Often areas of undulating landscape are found that are not too rugged to use for the production of biomass. Much of this land is characterized by gentle to rugged topography supporting savanna grasslands or xerophytic forests. The valleys support food crop production, while much of the upland areas support livestock grazing. About 10 million hectares in this region could potentially support forest vegetation mainly on middle to upper slopes.

3. Selva: East of the Andes lies the Selva which contributes the headwaters and comprises the Peruvian floodplain of the Amazon River and its numerous tributaries. The Selva is partitioned into the high and the low regions. The high Selva is characterized by a rolling topography with steep slopes. The high Selva occurs at elevations between 600 and 3,800 meters. The remainder is mainly comprised of alluvial soils in a flat topography.

Interspersed in this region are swampy areas that may be under water for much of the year. The Selva has most of the forested area of Peru, about 78 million hectares -- 69 million hectares in the basin and the remainder on the eastern slopes of the Andes.

Soils

In the Costa, the absence of significant precipitation is the major restraint on biomass productivity. Without the flushing action of water, the soils are often saline and possess pH values near 8.0. The low-lying valleys possess deep alluvial soils classed as Entisols (new soil without complete profile development). Aridisols (developed under arid conditions) comprise most of the remaining soils. The Aridisols are differentiated from the Inceptisols (soils with initial profile development) that occur in this area by noting if saturated extract conductivities of the soil are more than 2 mmhos per cm at 25°C in the 18 cm to 50 cm layer. Generally, soils in the region possess favorable fertility and physical properties for good percolation and drainage. High fertility occurs because water has not leached bases from the profile. The soils are moderately to highly susceptible to erosion should water be excessive. Properly irrigated and managed, these low-lying soils are highly productive, especially for food crops such as grains, potatoes, sugarcane, etc.

In the Sierra, soils occur on slopes of < 5% to as much as 70%. Just as slope varies widely, so do the soils occurring in the region. The principal soil groups are Entisols, Inceptisols, and Mollisols (dark, fertile topsoil, formed under grassland). Mollisols are formed under cold, cool, and warm conditions in the region. Some have thin surfaces while others are deep. In some cases, clay horizons occur below the surface layer. Among the other groups, similar wide variation occurs. The major difference resides with whether they formed under warm, humid, or seasonably dry conditions. Many of the soils occur on slopes at elevations only suitable for forests. The second most abundant group of soils are suitable for pasture and forests. These soils are erosive and occur at elevations less than 3,200 meters. The fertility of the soils in the Sierra ranges from low to high. Gully erosion is a serious problem. When leaching water is present, the soils may be infertile and acidic.

In the high Selva, well-developed soil profiles belonging to the Alfisol (clay subsurface high in bases) and Ultisol (clay subsurface low in bases) groups occur. Both possess clay accumulations in a subsurface horizon but differ in base content. Alfisols developed where a distinct dry season occurs. The Ultisols are highly weathered and leached of their bases. Where the soils are well-drained, the profile becomes oxidized and the iron-aluminum oxides impart a red color. In depressions and valleys, alluvial Inceptisols occur. In upland summit positions that are relatively stable Oxisols occur. These reflect a loss of silicon and the accumulation of iron and aluminum oxides within 2 m of the surface. In this group, infiltration is high and erodibility low since clays are aggregated and do not disperse readily in water.

In the low Selva, the soils are dominated by Entisols from recent alluvial deposits from river floodings (see Figure 4). The clay fraction of these soils is kaolinitic or hydrous oxides -- both low in exchange capacity. Thus, the soils are often low in fertility. The bulk of the nutrients occurs in the living and dead organic materials. Because of warm temperatures (18 to 24°C), high rainfall (1,500 to 7,000 mm) and decaying vegetation, weathering in these soils is intense. The resultant clay slows infiltration and percolation; thus, in the absence of vegetation, erosion is a serious problem. In some cases, the clays may dry irreversibly if conditions promoting excessive desiccation are created. For these reasons, many of the soils cannot persist under cultivation and support intensive cropping. Many of the soils of the Selva are compacted, and depleted of vegetable ash and topsoil when mechanically cleared. These adverse effects limit the feasibility of this practice and favor manual clearing. In the high Selva, where sloping land is common, erosion is a serious problem. Not only does erosion cause the loss of topsoil, but the stream sediments will adversely affect hydroelectric facilities. Because of these limitations, only about six million hectares appear suitable for pastures and two million hectares for cultivation. The remainder probably should remain in forests. Of the 70 million hectares, it is believed that as much as 25 million should be in watershed protection forests.

Figure 4: Typical Soil Profile of Selva Region.

Figure 5: Irrigated Coastal Mountain Valley in Costa Region.

Climate

Peru provides an interesting study of climatology. The country is essentially tropical, lying between the equator and 19° south latitude. However, the topography of the region gives rise to an interesting variety of climates. There are three great climatic groups (as defined by Papadakis, 1961) found in Peru: desertic; tierra fria or non-frostless tropical highlands; and tropical. The main reasons for the existence of these climates are the Andes mountains and the Von Humboldt ocean current. This combination has caused the development of an atmospheric weather pattern which has led to the creation of a desert on the western slopes of the Andes and a tropical rain forest on the mountains eastern side. The tropical highlands in the Andes are among the highest in the world. In Peru, these three climatic groups are present in the Costa, Sierra, and Selva regions, respectively.

As mentioned previously, the Costa is predominantly desert, but a large proportion of the country's agricultural production occurs in the coastal mountain river valleys (see Figure 5). It is necessary to irrigate the crops grown in this region and the water for this production is obtained from the snowmelts and rain in the Andes.

In the highland areas of the Andes are cool, rich, and fertile mountain valleys (see Figure 6). Much of the hillsides are used as pasture and intensive agricultural production occurs on the mountain valley floors. Because of the high altitue of the Andes, many parts of the Sierra are uninhabited and unsuitable for biomass production (see Figure 7).

The Selva or tropical area is potentially the most productive region in Peru, and is often identified as either the high Selva or the low Selva. The high Selva or Caja de Selva (rim of the Selva) is a mountainous tropical area with high rainfall (see Figure 8). The low Selva is the flat low lying reaches of the Amazon River Basin (see Figure 9).

Thus, the two major climatic variables in determining biomass productivity in Peru are temperature and rainfall. These data are presented in Tables 2 and 3, respectively. For represenative cities from the Costa (e.g., Lima), the Sierra (e.g., Huancayo), and the Selva (e.g., Tingo Maria), the typical climatic patterns of the hot-dry desert, the cool-moist highlands, and hot-moist tropics are evident.

Figure 6: Cultivated Mountainside in the Sierra Region.

Figure 7: Barren Terrain Typical of the High Sierra Region.

Figure 8: Highlands of the Caja de Selva (High Selva Region.)

Figure 9: Low Selva within the Amazon River Basin.

Table 2 Monthly Mean Temperatures (°C) for Selected Stations in Peru (Adapted From: Wernstedt, 1972)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arequipa	14.1	14.3	14.5	13.4	12.7	11.2	11.5	12.1	12.9	13.4	13.4	13.5	13.1
Cajamarca	14.65	14.1	14.2	13.8	13.9	13.2	13.1	14.0	14.5	14.3	14.6	14.3	14.0
Cartavio	23.0	24.1	23.8	22.0	21.0	19.2	18.3	18.0	17.9	18.2	19.0	20.7	20.4
Cerro de Pasco	2.8	2.4	3.3	2.1	1.6	2.1	1.3	2.6	2.2	2.6	3.6	3.1	2.5
Cuzco	12.0	11.4	11.9	11.4	10.2	9.5	8.8	10.2	11.5	12.3	12.9	12.4	10.9
Chacapoyas	15.9	15.7	15.6	15.4	15.8	15.2	14.5	15.1	14.1	15.9	16.5	16.2	15.6
Huancayo	12.1	12.0	11.7	11.6	10.2	9.8	9.3	10.2	11.9	12.4	12.7	12.2	11.2
Imata	4.5	4.7	4.7	3.7	1.9	1.4	1.6	1.0	2.2	2.7	3.6	4.5	2.9
Juanju	27.4	26.6	26.5	26.4	26.0	25.6	25.6	26.3	26.6	26.7	26.9	27.5	26.5
Lambayeque	25.1	26.4	26.2	24.6	22.8	20.9	19.6	19.3	19.7	20.2	21.1	22.8	22.9
Lima	21.4	22.2	22.4	19.8	17.5	15.6	15.2	15.0	15.4	16.2	17.4	19.1	18.0
Molina (La)	22.8	23.6	23.3	21.4	18.6	16.6	15.9	15.8	16.5	17.6	18.8	20.6	19.3
Piura	27.7	28.9	28.9	27.5	25.1	23.5	22.6	22.9	23.5	23.4	23.9	25.3	25.6
Puno	8.5	8.5	8.9	8.0	6.6	5.8	6.0	6.8	7.7	9.2	9.5	9.3	7.8
Tacna	20.6	20.7	19.4	17.6	15.1	13.4	12.7	13.0	14.0	14.9	17.0	18.4	16.5
Tingo Maria	22.8	22.1	22.4	22.3	22.4	21.8	22.0	22.6	22.5	22.8	26.6	23.4	22.5
Vitor	17.1	17.7	18.3	17.7	18.0	17.8	17.5	17.8	18.1	17.4	17.4	17.5	17.8

Table 3 Monthly Mean Rainfall (Centimeter) for Selected Stations in Peru (Adapted From: Wernstedt, 1972)

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arequipa	3.1	2.6	2.9	0.1	0.0	0.0	0.0	0.01	0.1	0.0	0.1	0.5	9.4
Cajamarca	9.5	11.3	13.6	10.8	3.7	1.3	0.5	0.9	3.0	8.7	7.2	7.7	78.2
Cartavio	0.1	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1	0.8
Cerro de Pasco	13.4	15.3	12.8	7.0	3.6	1.6	1.1	1.9	5.0	6.8	11.5	12.6	92.6
Cuzco	15.8	12.8	12.6	3.8	0.9	0.5	0.1	0.8	2.4	4.3	8.1	12.8	74.9
Chacapoyas	8.3	13.5	10.3	9.6	4.0	2.7	2.3	2.8	6.0	9.2	7.3	5.6	81.5
Huancayo	13.6	12.6	11.6	5.1	2.2	0.8	0.5	1.1	4.0	7.1	6.9	9.3	74.9
Imata	14.8	14.7	10.5	4.1	1.5	0.5	0.3	0.2	2.0	2.0	2.3	9.0	62.0
Iquitos	2.6	20.0	27.0	31.4	25.7	17.2	17.7	13.8	20.4	21.9	27.0	24.6	272.7
Juanju	9.2	15.9	14.1	20.3	12.7	6.3	8.0	6.0	12.2	16.8	15.3	10.8	147.6
Lambayeque	0.1	0.7	0.7	0.3	0.1	0.1	0.0	0.0	0.1	0.1	0.1	0.2	2.5
Lima	0.1	0.0	0.1	0.0	0.1	0.3	0.5	0.6	0.5	0.2	0.1	0.1	2.6
Molina (La)	0.1	0.16	0.1	0.1	0.2	0.3	0.3	0.3	0.2	0.1	0.1	0.1	2.0
Piura	1.1	1.7	1.9	1.5	0.1	0.0	0.0	0.1	0.0	0.1	0.1	0.6	7.2
Puno	13.5	13.8	10.9	4.0	0.9	0.6	0.5	0.6	2.4	3.7	2.7	8.8	62.5
San Ramon	24.2	24.4	24.3	20.4	12.0	5.4	7.1	11.6	12.8	16.6	12.4	21.9	194.1
Tacna	0.1	0.1	0.1	0.1	0.4	0.3	0.4	0.8	1.1	0.7	0.1	0.1	4.1
Tingo Maria	42.4	40.3	46.9	35.1	21.7	17.5	15.7	11.2	18.4	34.1	28.9	28.9	341.0
Vitor	0.8	0.8	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1	2.2

From the agronomic perspective, the method of climatological classification system developed by Papadakis (1961) can assist one understanding of biomass productivity in Peru. This classification approach takes into account those environmental factors which are determinants of agricultural productivity. The approach amounts to the development of an energy and water balance for a habitat. The energy balance is based on the severity of winters and the heat occurring during the summer and their relationship to agricultural productivity. An explanation of the winter severity and the summer heat classification approach is given in Appendix A and Appendix B, respectively. The overall effect of seasonal temperature variations is described by the Temperature Regime (see Appendix C). The water balance is determined by the Humidity Regime (see Appendix D for explanation), which is based on a humidity index (the ratio of annual rainfall to annual evapotranspiration (see Appendix E for evapotranspiration data)), normal and maximum excess rainfall, and length of humid and dry seasons. The resultant climatic classification thus allows an estimation of the environmental variables important for biomass production. The climatic classifications of twenty-three stations throughout Peru are presented in Table 4.

The distribution of vegetation types throughout Peru are depicted in four maps; one for each 4° latitude south (see Figures 10, 11, 12, and 13). These figures are vegetation maps for Peru adapted from maps developed by personnel at the Universidad Nacional Agraria. The original vegetation map identified twenty-two separate vegetative zones. The maps presented here depicts eight vegetation zones. Table 5 presents the legend for interpreting these maps. Upon inspection we find over 42% of Peru covered by alluvial or hilly forests, 22% by desert, 13% by protected forest area, 10% by agricultural lands, 6% by pasture, 4% by swamp-like areas, and 3% by savanna vegetation.

Table 4. Climatic Parameters, Regimes, and Classifications for Selected Locations in Peru
(Adapted from Papadakis, 1961)

Location	Humidity ¹ Index	Humid ² Season Normal Excess Rainfall (cm)	Maximum ³ Excess Rainfall (cm)	Humid Season Begin (End)	Dry Season Begin (End)	Winter ⁴ Severity Classification	Summer ⁵ Heat Classification	Humidity ⁶ Regime	Temperature ⁷ Regime	Climatic Classification
Arequipa	.10	0	4	None	Mar. (Jan.)	Citrus Belt	Maize Belt	Semi-arid Monsoon	Medium Tierra Fria	Medium Tierra Fria
Cajamarca	.75	11	67	Dec. (Apr.)	July (Aug.)	Citrus Belt	Maize Belt	Dry Monsoon	Medium Tierra Fria	Medium Tierra Fria
Cartavio	.02	0	0	None	Jan. (Dec.)	Cool Tropical	Coffee Belt	Absolute Desert Humid	Cool Tropical Low	Cool and Semi-hot tropical Desert
Cerro de Pasco	1.54	36	>99	Oct. (Apr.)	None	Cold Winter Oats Belt	High Alpine Belt	Humid	Low Andine	High Andine
Chacha Poyas	1.01	18	86	Dec. (Apr.)	August	Cool Tropical Belt	Maize Belt	Moist Monsoon	Cool Tierra Templada	Humid Tierra Templada
Chuquibambilla	.80	27	80	Dec. (Mar.)	June (Oct.)	Mild Winter Wheat Belt	High Alpine Belt	Moist Monsoon	Low Andine	High Andine
Cusco	.71	22	77	Dec. (Mar.)	June (Sept.)	Mild Winter Oats Belt	Maize Belt	Moist Monsoon	Medium Tierra Fria	Medium Tierra Fria
Huancayo	.71	20	86	Dec. (Mar.)	June (Sep.)	Mild Winter Oats Belt	Maize Belt	Moist Monsoon	Medium Tierra Fria	Medium Tierra Fria
Imata	.98	35	93	Dec. (Mar.)	June (Nov.)	Mild Winter Wheat Belt	High Alpine Belt	Moist Monsoon	Low Andine	High Andine
Iquitos	2.42	187	>99	Aug. (July)	None	Equatorial Belt	Cool cotton Belt	Ever-humid	Semi-hot Equatorial	Humid Semi-hot Equatorial

Table 4. (contd.)

Location	Humidity ¹ Index	Humid ² Season Normal Excess Rainfall (cm)	Maximum ³ Excess Rainfall (cm)	Humid Season Begin (End)	Dry Season Begin (End)	Winter ⁴ Severity Classification	Summer ⁵ Heat Classification	Humidity ⁶ Regime	Temperature ⁷ Regime	Climatic Classification
Jauja	.75	.17	61	Dec. (Mar.)	July (Sept.)	Citrus Belt	Maize Belt	Moist Monsoon	Medium Tierra Fria	Medium Tierra Fria
Lambayeque	.02	0	0	None	Jan. (Dec.)	Tropical Belt	Cool Cotton Belt	Absolute Desert	Semi-hot Tropical	Cool and Semi-hot tropical desert
La Molina	.02	0	0	None	Sept. (Aug.)	Cool Tropical	Coffee Belt	Absolute Desert	Cool Tropical	Cool and Semi-hot Tropical Desert
Lima	.05	0	0	None	Sep. (Aug.)	Cool Tropical Belt	Coffee Belt	Absolute Desert	Cool Tropical	Cool and Semi-hot Tropical Desert
Lomas de Lachay	.46	6	18	Jul. (Sept.)	Jan (May)	Cool Tropical Belt	Maize Belt	Dry Mediterranean	Cool Tropical	Tropical Mediterranean
Mollendo	.03	0	0	None	Sept. (Aug.)	Cool Tropical	Coffee Belt	Absolute Desert	Cool Tropical	Cool and Semi- hot Tropical Desert
Moquegua	.00	0	0	None	Mar. (Feb.)	Citrus Belt	Coffee Belt	Absolute Desert	Low Tierra Fria	Tropical Highland Desert
Piura	.06	0	0	None	Mar. (Feb.)	Cool Tropical Belt	Warm Cotton Belt	Monsoon Desert	Hot Tropical	Hot tropical Equatorial Desert
Puno	.70	20	66	Dec. (Mar.)	June (Nov.)	Mild Winter Oats Belt	Low Alpine Belt	Moist Monsoon	Low Andine	Low Andine

Table 4. (contd.)

Location	Humidity ¹ Index	Humid ² Season Normal Excess Rainfall (cm)	Maximum ³ Excess Rainfall (cm)	Humid Season Begin (End)	Dry Season Begin (End)	Winter ⁴ Severity Classification	Summer ⁵ Heat Classification	Humidity ⁶ Regime	Temperature ⁷ Regime	Climatic Classification
San Ramon	1.20	51	>99	Oct. (May)	None	Tropical Belt	Coffee Belt	Humid	Tierra Templada	Humid Tierra Templada
Tacna	.03	0	0	None	July (June)	Cool Tropical Belt	Coffee Belt	Absolute Desert	Cool	Absolute Cool Tropical Desert
Tingo Maria	2.48	198	>99	Sept. (July)	None	Tropical Belt	Coffee Belt	Humid	Tierra Templada	Humid Tierra Templada
Vitor	.01	0	0	None	Mar. (Feb.)	Citrus Belt	Coffee Belt	Absolute Desert	Low Tierra Fria	Tropical Highland Desert

¹ Humidity index = $\frac{\text{Annual Rainfall}}{\text{Annual Evapotranspiration}}$

² The difference: rainfall minus evapotranspiration during the humid season.

³ The difference: two times rainfall minus evapotranspiration during the non-dry season.

⁴ See Appendix A for explanation.

⁵ See Appendix B for explanation.

⁶ See Appendix C for explanation.

⁷ See Appendix D for explanation.

Table 5. Legend for Vegetation Maps of Peru

Main Vegetative Groups	Vegetative Subgroups	Symbol
Forest, Alluvial	Forest, Alluvial Class I
	Forest, Alluvial Class II	
	Forest, Alluvial Class III	
Forest, Hilly	Forest, Hilly Class I
	Forest, Hilly Class II	
	Forest, Hilly Class III	
Swamp Vegetation	Mangroves
	Aguaíal	
	Swamps	
	Quinal	
Protected Forest	Devastated Forests
	Inaccessible Forests	
	Plantations	
Savanna and Low Bush Vegetation	Dense Dry Forest
	Savanna Forest	
	Chaparral	
	Podocarpus Forest	
	Low Bush	
Desert Vegetation	Cactus
	Bush	
Agricultural Vegetation	Food and Fiber Crops
Pasture	Forage
	Crops

Fig. 10. Vegetation Map of Peru (0-4° South Latitude)
(Adapted from Mapa Forestal, 1975)

Fig. 11. Vegetation Map of Peru (5-9° South Latitude)
(Adapted from Mapa Forestal, 1975)

Fig. 12. Vegetation Map of Peru (10-13° South Latitude)
(Adapted from Mapa Forestal, 1975).

Fig. 13. Vegetation Map of Peru (14-18° South Latitude)
(Adapted from Mapa Forestal, 1975).

IV. BIOFUEL RESOURCE BASE

CURRENT AGRICULTURAL RESOURCES

In Peru, approximately 2,600,000 hectares out of a total surface area of 128.5 million hectares is cultivated. An additional 27.3 million hectares can be classified as uncultivated grasslands (Ministry of Agriculture and USAID, 1971). Of the land under cultivation, over 40% (approximately 1.1 million hectares) is irrigated. Cereal crops account for around 35% of the total cultivated and 32% of the irrigated area. Tuber crops, such as potatoes, cassava, and sweet potatoes, are grown on approximately 14% of the total cultivated area and 7% of the irrigated area. Cultivated pastures (e.g., alfalfa) and other forages cover over 15% of the cultivated area and 19% of the irrigated area. Permanent cultivars, such as lemons, olives, cocoa, tea, coffee, etc., total around 10% of the cultivated area and 7% of the irrigated land, while fruits and vegetables cover about 9% of cultivated land and 7% of irrigated land. Beans and assorted legumes account for over 6% of the cultivated area and 5% of the irrigated area. Over 11% of the cultivated area is for the production of industrial crops, such as sugarcane and cotton; these crops require 23% of the irrigated acreage. The production and yield statistics for selected crops are presented in Table 6.

The Costa region contains 27% of the total cultivated area in Peru and two-thirds of the irrigated land. Virtually all agriculture on the coast is irrigated. This area accounts for 75% of rice production, 58% of corn production, 86% of sweet potato production, 99% of cotton production, and over 99% of sugar production in Peru (see Table 7). The biofuel potential of this area, as estimated from the crops listed in Table 7, is approximately 53 JQ's (10^{15} joules) per year with two-thirds of this amount coming from sugarcane production. Much of the sugarcane residue is currently being utilized by the sugar industry for boiler fuel. Also, over 30 million liters of ethanol is produced in the sugar districts here (see Table 8). An additional 18 JQ's of biofuel energy could possibly be obtained from the livestock population in the Costa region (see Table 9).

In the Sierra, 50% of the area cultivated and 30% of that irrigated in Peru is found. Continuous cultivation in this region is rare and a fallow system of crop rotation is usually followed. It has been estimated

Table 6. Production, Residue, and Energy Estimates of Crops Grown in Peru

Commodity	1976 ¹ Production (Metric tons)	1976 ¹ Yield (Metric tons/ Hectare)	Annual Residue Production Estimate (Metric Tons)	Estimated Residue ² Energy Value (10 ¹⁵ Joules)
Rice	570,415	4.28	855,623	11.47
Oats	741	.83	1,482	.02
Barley	149,517	.92	224,276	3.00
Milo	465	.85	465	.01
Maize	725,659	1.88	725,659	9.72
Quinoa	8,676	.58	21,690	.29
Sorghum	45,945	3.13	68,918	.92
Wheat	127,497	.95	191,246	2.56
Soybean	2,869	1.42	4,303	.06
Plantains	711,065	11.45	106,660	1.42
Camote	162,547	11.51	24,382	.32
Potatoes	1,167,000	6.59	250,050	3.25
Yuca	402,486	11.23	402,486	5.23
Cotton	164,511	1.67	164,511	2.20
Peanut	3,647	1.26	3,647	.05
Sugarcane (For Sugar)	8,791,542	159.86	3,077,040	33.85
Sugarcane (For Alcohol)	185,170	54.14	64,810	.71
Sugarcane (For Molasses)	233,050	53.88	81,568	.90
Coconut	1,311	7.95	1,967	.03
Aguafe	5,460	21.00	5,460	.07

¹ Anuario Estadístico Agropecuario (1976) Ministerio de Agricultura y Alimentación OSEI, Lima, Peru.

² See Appendix F for explanation.

Table 7. Production, Residue, and Energy Estimates of Crops Grown in the Costa Region of Peru

Commodity	1976 ¹ Production (Metric Tons)	1976 ¹ Yield (Metric Tons/ Hectare)	Annual Residue Production Estimate (Metric Tons)	Estimated Residue ² Energy Value (10 ¹⁵ Joules)
Rice	426,431	4.88	639,647	8.57
Oats	—	—	—	—
Barley	2,570	2.37	3,855	.05
Milo	—	—	—	—
Maize	417,444	3.45	417,444	5.59
Quinua	—	—	—	—
Sorghum	45,145	3.16	67,718	.91
Wheat	3,824	2.04	5,736	.08
Soybean	2,301	1.42	3,452	.05
Plantain	113,020	12.84	16,953	.22
Camote	139,313	13.34	20,897	.27
Potatoes	156,948	13.85	23,542	.31
Yuca	50,392	10.67	50,392	.66
Cotton	162,869	1.69	162,869	2.18
Peanut	967	2.54	967	.01
Sugarcane (for sugar)	8,761,542	159.90	3,066,540	33.73
Sugarcane (for alcohol)	41,958	59.58	14,685	.16
Sugarcane (for molasses)	67,350	84.19	23,573	26

¹Anuario Estadístico Agropecuario (1976) Ministerio de Agricultura y Alimentación OSEI, Lima, Peru

²See Appendix F for explanation.

Table 8. Production of Absolute Ethanol in Peru by Sugar Producing District

	FY 1972				FY 1974				FY 1976			
	Absolute Ethanol Production (1000 L)	Yeast Recovered (Mt/Yr)	Yeast for Fodder (Mt/Yr)	CO ₂ Produced (Mt/Yr)	Absolute Ethanol Production (1000 L)	Yeast Recovered (Mt/Yr)	Yeast for Fodder (Mt/Yr)	CO ₂ Produced (Mt/Yr)	Absolute Ethanol Production (1000 L)	Yeast Recovered (Mt/Yr)	Yeast for Fodder (Mt/Yr)	CO ₂ Produced (Mt/Yr)
Faramonga	4,996	71	749	2500	5,184	74	852	2590	5,065	72	760	2530
Pomalca	881	13	132	440	1,104	16	166	552	1,414	20	212	707
Pucala	--	--	--	--	3,795	54	569	1900	3,540	51	531	1707
Tuman	3,341	48	501	1670	2,831	41	425	1415	2,863	41	430	1431
Chucarapi	728	10	109	364	868	12	130	434	627	9	94	313
Sta. Maria	4	.05	.55	2	--	--	--	--	--	--	--	--
Cartavio	10,590	151	1588	5295	10,717	153	1608	5358	11,235	161	1685	5617
Cana Grande	7,942	114	1191	3971	8,941	128	1341	4470	4,968	71	745	2484
Laredo	--	--	--	--	1,143	16	171	571	692	10	103	346

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SOURCE: Banco de la Nacion, Div: Alcoholes y Bedidad (August, 1977).

Table 9. Residue Production and Energy Potential From Livestock in Peru

Animal	1976 Population ¹ (1000 Head)	Annual Residue Production Estimate (1000 Metric Tons)	Estimated Residue ² Energy Value (10 ¹⁵ Joules)
<u>Alpacas</u>			
National	2,445	318	4.64
Sierra	2,445	318	4.64
<u>Poultry</u>			
National	37,681	42	.61
Costa	28,374	32	.46
Sierra	6,671	7	.10
Selva	2,637	3	.05
<u>Goats</u>			
National	2,021	222	3.24
Costa	728	80	1.17
Sierra	1,278	140	2.04
Selva	16	2	.03
<u>Horses</u>			
National	1,327	1,991	29.07
Costa	123	185	2.70
Sierra	1,138	1,707	24.92
Selva	66	99	1.45
<u>Llamas</u>			
National	1,361	23	.34
Sierra	1,361	23	.34
<u>Sheep</u>			
National	15,294	1,682	24.56
Costa	241	26	.38
Sierra	15,025	1,653	24.13
Selva	27	3	.05
<u>Pigs</u>			
National	2,142	236	3.45
Costa	587	65	.95
Sierra	1,309	144	2.10
Selva	246	27	.40
<u>Cattle</u>			
National	4,189	7,121	103.97
Costa	509	865	12.63
Sierra	3,327	5,656	82.58
Selva	353	600	8.76

¹ Anuario Estadístico Agropecuario (1976) Ministerio de Agricultura y Alimentación, OSEI, Lima, Peru.

² See Appendix F for explanation.

that 500,000 hectares, approximately 20% of all cultivated land in Peru, lies fallow each year (Watters, 1971). Land will typically lie fallow 1-2 years for each year of crop production depending upon the soil type. Cereal (40%) and tuberous crops (20%) account for over 60% of the cultivated land in this mountainous area. Over 98% of the barley, all the oats, 33% of the corn, all the quinoa, 99% of the sorghum, 97% of the wheat, and 90% of the potatoes in Peru are grown in this region (see Table 10). The potentially available biofuel energy from the crop residues of the Sierra is approximately 16 JQ's. The animal population of the Sierra is quite large. Virtually all of the country's alpacas, goats, horses, llamas, and pigs and 80% of the cattle in Peru are found in this region (see Table 9). The manures produced by these animals provide approximately 140 JQ's of energy annually. Much of this energy is utilized for heating and cooking, or as fertilizer.

The Selva is potentially the most productive agricultural area of Peru and contains 23% of the cultivated area. Shifting cultivation predominates in this region with the particular sequencing of crops dependent upon locale. A typical sequence would involve slashing and burning a hectare of jungle, then planting maize or rice followed by yucca (cassava), then bananas and mangoes or some other fruit tree. The land is then allowed to return to jungle. The major crops (see Table 11) are plantains (78% of Peruvian production), cassava or yucca (78% of Peruvian production), and rice (25% of Peruvian production). The total biofuel energy, which could potentially be contained in crop residues of the Selva, is 6 JQ's and that from animal wastes approximates 11 JQ's. The reason for the comparatively lower biofuel production from agriculture in this area is because of the type of crops grown and lower yields. The agriculture in this area is currently developing and could eventually become the major agricultural region of Peru.

In summary, it has been estimated that 246 JQ's of energy are produced by agriculture in Peru; approximately one-third (76 JQ's) from crop residues, and two-thirds (170 JQ's) from animal residues. Sugarcane residues in the Costa and animal waste (dung) in the Sierra are currently the most utilized in the country.

Table 10. Production, Residue and Energy Estimates
of Crops Grown in the Sierra Region of Peru

Commodity	1976 ¹ Production (Metric Tons)	1976 ¹ Yield (Metric Tons/ Hectare)	Annual Residue Production Estimate (Metric Tons)	Estimated Residue ² Energy Value (10 ¹⁵ Joules)
Rice	1,593	4.55	2,390	.03
Oats	741	.82	1,482	.02
Barley	146,947	.91	220,421	2.95
Milo	465	.85	465	.01
Maize	236,915	1.07	236,915	3.18
Quinoa	8,676	.58	21,690	2.91
Sorghum	—	—	—	—
Wheat	123,673	.94	185,510	2.49
Soybean	—	—	—	—
Plantains	45,219	9.41	6,782	.09
Camote	17,149	5.80	2,572	.03
Potatoes	1,499,792	6.26	224,969	2.93
Yuca	37,749	7.43	37,749	.49
Cotton	126	.97	126	.00
Peanut	—	—	—	—
Sugarcane (for sugar)	30,000	150.00	10,500	.12
Sugarcane (for alcohol)	34,400	67.45	12,040	.13
Sugarcane (for molasses)	97,710	54.44	34,199	.38
Coconut	—	—	—	—
Aguaje	—	—	—	—

¹ Anuario Estadístico Agropecuario (1976) Ministerio de Agricultura Y Alimentación OSEI, Lima, Peru.

² See Appendix F for explanation.

Table 11. Production, Residue, and Energy Estimates of Crops Grown in the Selva Region of Peru

Commodity	1976 ¹ Production (Metric Tons)	1976 ¹ Yield (Metric Tons/ Hectare)	Annual Residue Production Estimate (Metric Tons)	Estimated Residue ² Energy Value (10 ¹⁵ Joules)
Rice	142,391	3.13	213,587	2.86
Oats	—	—	—	—
Barley	—	—	—	—
Milo	—	—	—	—
Maize	71,300	1.66	71,300	.96
Quinoa	—	—	—	—
Sorghum	800	2.00	1,200	.02
Wheat	—	—	—	—
Soybean	568	1.40	852	.01
Plantain	552,806	11.40	82,921	1.08
Camote	6,085	8.34	913	.01
Potatoes	10,260	5.70	1,539	.02
Yuca	314,345	12.07	314,345	.09
Cotton	1,516	.75	1,516	.02
Peanut	2,680	1.07	2,680	.04
Sugarcane	—	—	—	—
(for sugar)				
Sugarcane	88,390	61.38	30,937	.34
(for alcohol)				
Sugarcane	67,990	39.30	23,797	.26
(for molasses)				
Coconut	1,311	7.95	1,967	.03
Aguafe	5,460	21.00	5,460	.07

¹ Anuario Estadístico Agropecuario (1976) Ministerio de Agricultura y Alimentación OSEI, Lima, Peru.

² See Appendix F for explanation.

AGRICULTURAL RESOURCE POTENTIALS

The need to provide food for the people of the nation will restrict the capability of agricultural sector to provide biofuels to satisfy the future demand for energy. In 1976, 13% of the GNP was from agriculture and 40% of the labor force worked in this sector. An unfavorable balance of payments in agricultural trade amounting to a \$33 million deficit was registered in that year also. Most likely, increases in agricultural production will be offset by increases in population. Thus, the use of agriculturally productive land for energy production does not currently appear feasible.

Agricultural alternatives for providing alternative energy resources by 1985 rests primarily in the development of the agro-industrial base in the country. For example, increasing sugar production would simultaneously increase the availability of bagasse for energy conversion. The development of other agro-industries could similarly provide processing wastes which could be readily converted into a biofuel resource.

However, the use of marginal lands and the development of new agricultural approaches, such as fertilization to allow more fallow land to be cultivated, could make the outlook brighter. Certain high-residue crops like *Chenopodium quinoa* (see Figure 14) can be grown on marginal lands. *C. quinoa* has utility as both a food crop and potentially as a fuel crop. It can be naturally self-propagating and by planting it in the marginal highland areas of the Sierra, it can also provide protection from erosion. Other food/fuel crops like *C. quinoa* should be identified for future biofuel applications. Several candidates are potato and cassava, which could be fermented into ethanol in times of surplus or sold as food when scarce.

Double or multiple cropping practices could significantly increase crop production. The identification of multiple cropping schemes for various areas in Peru should also consider the feasibility of a food/fuel crop rotation. Thus, by employing multiple cropping for energy production, no additional land effectively would be removed from food production.

Developing the Selva for crop production could increase greatly the area of Peru under cultivation. This approach could open new lands for the production of biofuel crops. However, it should be seen as a long-term

Figure 14: *Chenopodium Quinoa*:
A Crop Which Could Provide Both
Food and Fuel.

Figure 15: Coppiced Stand of Eucalyptus (Photo Courtesy of
R. Giesecke, Member Peruvian Energy Assessment Team.)

venture because the development of environmentally sound approaches for production agriculture in this tropical area needs to occur.

In summary, three avenues appear open for agricultural approaches to biofuel production. One is the use of marginal or underutilized lands for the production of food/fuel crops. Another is the development of multiple cropping approaches of alternating crops for food and crops for fuel in a single year. The third is the development of the Selva for agricultural production.

CURRENT FOREST RESOURCES

Peru possess over 128 million hectares of land (Table 12) divided among 22 land types supporting vegetation. Although most of the forests are natural, plantations are becoming increasingly abundant and well-dispersed (Table 13). Unfortunately, most of the forest growth occurs remote to the major population centers. Of the total acres in forests (84.5 million hectares), about 75.5 million hectares are in the Selva (Table 14). Plantations mainly of eucalyptus are increasing rapidly in the Sierra (Table 13). For example, the area planted in 1973 was about 8,000 hectares; in 1976, 37,800 hectares to bring the total in Peru to 106,140 hectares (Table 13).

Outside Brazil, the Peruvian Amazon represents the greatest potential for forest products in South America. There are two regions in the Amazon -- the low-lying (alluvial forests) and the humid forests on the slopes of the Andes (Ceja de Selva) which are hilly but support high wood volumes (Table 12). As noted earlier, this region has rainfall from 1,500 to 7,000 mm, but the soils are low in fertility. Temperature averages range from 18°C for the high Selva to 24°C for the low Selva. In the undisturbed state, these conditions favor rapid growth.

Inventory statistics (Tables 12, 13, 14, 15) reflect the massive commercial volumes of timber especially in the Selva. For biofuel assessment, these statistics have limited value. First, only a few (Table 15) of the several hundred tree species comprising these forests are used commercially. Secondly, because of the abundance of forested hectares, only the largest trees are chosen. Generally, only trees with a top diameter of 40

TABLE 12: DISTRIBUTION OF LAND TYPES IN PERU BY AREA, REGION, PRODUCTIVITY AND DOMINANT SPECIES (1973)

LAND TYPE	AREA MILLIONS ha	VOLUME m ³ /ha	NUMBER TREES/ha	MOST ABUNDANT SPECIES	COSTA ha	SIERRA ha	SELVA ha	PERCENTAGE
Forest, Alluvial								
Class I	3.612	140-180	120(a)	Cumalo, Moena, Machimango, Shimbillo, Copal, Quinaquina	-	-	3.612	2.81
Class II	7.375	100-130	100(a)	Cumalo, Copal, Machimango, Zapote, Huimba, Shimbillo, Moena	-	-	7.375	5.74
Class III	5.071	80-100	65(a)	Oje, Palo Azufre, Requirá, Cumalo, Lagarto, Caspi, Cetico	-	-	5.071	3.94
Forest, Hilly								
Class I	12.754	140-180	110(a)	Tornillo, Moena, Quinillo, Cumalo, Mashonaste, Copal, Pashaco, Chimieva	-	-	12.754	9.92
Class II	16.169	120-150	90(a)	Tornillo, Moena, Quinillo, Cumalo	-	-	16.169	12.58
Class III	9.841	70-120	70(a)	Tornillo, Moena, Quinillo, Cedro, Pashco	-	-	9.841	7.66
Manglar	0.028	-	-	Mangle, Deli, Avicenia, Cono- carpus	0.028	-	-	0.02
Forest, Dry Dense	0.525	40	110(b)	Guayacan, Palo de Vaca, Amarillo, Sanchez, Zapote, Pasallo	0.525	-	-	0.41

TABLE 12 CONTINUED

LAND TYPE	AREA MILLIONS ha	VOLUME m ³ /ha	NUMBER TREES/ha	MOST ABUNDANT SPECIES	COSTA ha	SIERRA ha	SELVA ha	PERCENTAGE
Forest, Savanna	1.121	12-15	30(b)	Algarrobo, Zapote, Huarango, Hualtaco, Palo Santo, Ceibo	1.121	-	-	0.87
Chapparel	0.898	-	-	Algarrobo, Zapote, Sauce, Acacias	0.898	-	-	0.70
Quinual	0.006	20-50	500	Quena	-	.006	-	0.005
Forest, Podocarpus	0.408	70-75	65(a)	Romerillo, Ulcumano, Moena, Cumalo, Puma, Maqui, Paltron, Roble	-	-	.408	0.32
Palm Forests	1.053	-	580	Aguaaje, Huasai, Ungurahui	-	-	1.053	0.82
Bush Land	1.086	-	-	Tara, Pallilo, Mito, Sauce, Molle	1.086	-	-	0.84
Land Suitable for Plantations	2.336	-	-	Shrubs, Grasses	-	2.336	-	1.82
Swamp	3.502	-	-	Aguaaje, Palms	-	-	3.502	2.72
Forests Devastated by Agriculture Class I	5.191	70	-	-	-	-	5.191	4.04
Forests Inaccessible Because of Slope	8.667	100-120	100	-	-	-	8.667	6.74
Desert	28.709	-	-	-	28.709	-	-	22.34
Grassland	7.929	-	-	-	*	*	-	6.17
Agricultural Use-- Trees and Cultivated	12.201	-	-	Various Crops and Casuvina, Eucalyptus, Cypress	*	*	*	9.49

TABLE 12 CONTINUED

LAND TYPE	AREA MILLIONS ha	VOLUME m ³ /ha	NUMBER TREES/ha	MOST ABUNDANT SPECIES	COSTA ha	SIERRA ha	SELVA ha	PERCENTAGE
Forest Plantations	0.038	-	-	Eucalyptus, Pinus	-	*	*	0.03
TOTAL	128.521	-	-	-	-	-	-	100.00

(a) 25cm diameter or larger

(b) 15cm diameter or larger

*Not proportioned

Source: Orjeda, Jorge Malleux. 1975. Mapa Forestal del Peru. Dept. de Manejo Forestal.
Univ. Nac. Agrar. La Molina. 161 pp.

TABLE 13: FOREST PLANTATION DEVELOPMENT IN PERUVIAN DEPARTMENTS

DEPARTMENT	YEAR				TOTAL
	1964	1968	1973	1976	
	HECTARES				
Tumbes	1.0	3.0	68.4	-	463
Piurra	-	10.0	109.3	300	2,201
Lambayeque	4.0	10.0	-	-	552
Cajamarca	-	165.0	670.0	549	7,261
Amazonas	-	-	411.0	-	2,913
La Libertad	5.0	17.0	326.5	500	5,053
Ancash	6.0	634.6	706.0	500	9,395
Ica	-	15.0	13.0	-	323
Arequipa	19.0	24.0	71.0	30	992
Tacna	-	-	12.0	22	567
Lima	15.0	40.0	28.0	-	1,090
Moquegua	-	-	5.0	-	242
Junín	485.2	411.0	274.0	169	18,798
Huanuco	-	370.5	451.7	300	5,433
Pasco	-	117.0	29.5	140	2,353
San Martín	-	-	-	-	6
Huancauelica	-	1.0	81.5	-	1,447
Loreto	-	-	-	-	708
Ayacucho	-	65.7	368.0	100	2,462
Azeo	482.6	660.8	1,943.0	2,013	27,416
Apurímar	15.0	326.4	2,286.4	1,084	15,758
Madre de Dios	-	-	3.5	-	70
Puno	-	10.0	150.0	10	637
TOTAL	1,017.8	2,841.0	7,980.4	37,781	106,140

Eucalyptus comprises about 98% and other species the remainder.

Source: Orjeda, Jorge Malleux. 1975 (See Table 12) and Ministerio de Agricultura. Vademecum Forestal. Lima, Peru. 1977. 133 pp.

TABLE 14: NATURAL FOREST IN PERU AND LAND CAPABLE OF SUPPORTING
FOREST PLANTATIONS (1976)

REGION	NATURAL FOREST	PLANTATIONS	LAND SUITABLE FOR PLANTING	TOTAL
			HECTARES	
Costa	950,000	6,683	493,317	1,450,000
Sierra	50,000	97,672	7,402,328	7,550,000
Selva	73,000,000	1,785	2,498,215	75,500,000
TOTAL	74,000,000	106,140	10,393,860	84,500,000

Source: Ministerio de Agricultura (See Table 13).

TABLE 15: PRODUCTION OF SAWN FOREST PRODUCTS BY SPECIES

SPECIES	YEAR		
	1968	1972	1975
		m ³	
Alfaro	3,411	3,884	7,890
Caoba	18,312	21,176	26,094
Cafahua	178	105	7,220
Cedro	70,815	83,997	68,513
Congoma	1,511	-	5,135
Copaiga	2,470	2,292	17,898
Cumalo	1,222	13,311	10,780
Diablo fuerte	2,025	3,637	3,088
Ishpingo	1,330	1,538	3,783
Lupuna	15,787	8	1,665
Marupa	-	-	1,330
Moena	2,642	11,814	20,753
Mogal	1,600	1,258	1,827
Roble amarillo	4,466	7,084	7,467
Roble corriente	68,472	13,797	108,608
Tornillo	5,756	30,003	59,263
Ulcumano	3,855	3,884	4,398
Eucalypto	17,134	67,026	85,047
Others	48,341	114,812	52,881
TOTAL	269,327	379,626	513,640

Source: Ministerio de Agricultura (See Table 14).

cm or larger are included in inventories. Because logs are often transported by river rafting, only the species that float are often chosen. Generally, about 25 species are used at all and 44% of the utilization belongs to four species. Where mechanical harvest and over-the-road transportation is possible, additional species are exploited.

Currently, not more than 2.7% of the forests are exploited and then only one cubic meter/ha or less is harvested (Dourojeanni, 1975). This usage represents less than one percent of the annual growth -- about 0.006 percent of the standing volume.

Estimates of the standing volumes vary widely. In this report, the conservative estimates were chosen (Table 12). Based on commercial uses, vast amounts of unused biofuels are left in the forests because ways to use them are not known, the wood will not float, or wood is lost to decay awaiting high water. This added to slash (limbs and small stems) from commercial trees suggests that much biomass which potentially could be used for fuel is left in the forest.

Once a log is delivered to a mill site (Table 16), mill waste may represent from 50% to 70% of the overall lumber processed (Dourojeanni, 1975). These wastes are often burned for disposal purposes. It appears that they could be used as biofuels. To point up this wastage, compare the data for extraction (harvests) volumes (Table 16) with the processed volumes (Table 17). From these tables, it can be calculated for 1975 production that approximately 503,000 m³ of waste was generated by the Peruvian forest products industry. Assuming a density of 500 kg/m³ and a heating value of 18,000 million joules per metric ton, this waste contains 4.5 JQ's of energy.

Plantations, mainly of eucalyptus, are increasingly planted in Peru (Table 13), especially in the Sierra. These cultured forests which grow from 10 to 18 m³/ha/yr now possess over one million m³ (Table 18). During the study on Peru, large eucalyptus plantations were observed in the highland of Cusco (at this opportunity *E. globulus* was observed growing at 400 m) (12,000 ft). In Cajamarca, *E. globulus*, *E. camaldulensis*, and *E. salignas* were growing at 2500 m (7,000 ft) in experimental plantation of the Servicio Silvo Agropecuario U.N.T.C. A successful establishment and

TABLE 16: EXTRACTION OF ROUND WOOD FOR PROCESSING IN PERU

	1968	1972	1975
	m ³		
Sawn Timber	490,175	690,919	934,825
Parquet	20,086	30,943	20,189
Plywood	27,931	58,832	39,068
Veneer	27,441	51,630	73,545
Particle Board	11,881	9,799	10,594
Decorative Hardboard	1,539	2,079	2,081
Rail Ties	2,830	3,604	1,507
	581,883	847,806	1,081,809
Firewood	2,081,960	2,369,215	2,580,185
Charcoal	27,951	31,112	19,206
Pulpwood	-	54,333	22,450
Rural Construction (Homes and Fences)	268,743	329,678	370,006

Source: Ministerio de Agricultura (See Table 13).

TABLE 17: PRODUCTION OF FOREST PRODUCTS IN PERU

	1968	1972	1975
		m ³	
Sawn Boards	268,327	379,626	513,640
Parquet	5,624	8,664	5,653
Plywood	12,144	25,579	16,986
Veneer	11,931	22,448	31,976
Particle Board	9,139	7,538	8,149
Decorative Hardboard	810	1,094	1,095
Rail Ties	1,555	1,980	8,288
	310,530	446,929	578,327
Firewood	2,081,960	2,369,215	2,580,185
Charcoal	27,951	31,112	19,206
Wood Pulp	*	54,333	22,450

*Information Not Available.

Source: Ministerio de Agricultura (See Table 13).

TABLE 18: WOOD PRODUCTION BY PLANTATIONS
IN PERU*

YEAR	VOLUME OF WOOD IN PLANTATIONS
	m ³
1964	208,200
1966	163,800
1968	579,200
1970	737,200
1972	1,532,400
1974	1,940,800
1976	1,143,400

Source: Ministerio de Agricultura (See Table 13).

*Assuming 10m³/ha/year for 20 years.

rapid growth of *E. deglupta* was observed in a plot in the experimental farm operated by the Ministerio de Agricultura, Zona Agraria IX, Tarapoto. In the city of Lima, many eucalyptus, mainly globulus, are planted in main avenues and parks.

These natural forests are estimated to grow about 10 to 30 m³/ha/yr. Assuming that the average Selva forest is useful for forest production and 60% harvestable, these 43 million hectares would grow between 430 to 1,290 million m³ per year and this wood could be used for energy without reducing the current standing forest stock. This growth represents 3,900 to 11,000 JQ's.

In spite of Peru's massive potential for forest growth, the country increasingly imports forest products (Table 19) and has not developed its export potential. Striking among the imports is the considerable volume of coniferous wood (Table 20) probably to meet the softwood fiber needs, especially for pulp. Currently, only one pulp mill uses Peruvian wood (Table 21), while the remainder use bagasse. A well-developed forest industry could generate substantial amounts of biofuels and lend support to managed forests over the currently exploited forests that are rapidly being degraded by timbering and shifting agriculture. Peruvians only use 0.25 m³ of wood per capita per annum but import pulp and paper valued at 900 million soles per annum (Dourojeanni, 1975). In the remainder of Latin America, 1.2 m²/capita/yr are used while inhabitants of developed countries use more than 2 m³. The potential for expanding wood use (wood is an energy-efficient building material in comparison to the energy requirement for concrete, steel, aluminum alternatives) and the energy content of the commercial wood volumes in Peru are shown in Table 22. The energy content of this wood volume is estimated to range from 78,370 to 97,620 JQ's

FOREST RESOURCE POTENTIALS

The forest resources in Peru are immense and will remain substantial even if exploitive forestry should continue. Although local plantings could be made in the Costa primarily for fuelwood and rural use, expanding forests in this area shows little promise. Climatic conditions are unsuitable

TABLE 19: IMPORTATION AND EXPORTATION
OF FOREST PRODUCTS IN PERU

YEAR	IMPORTS	EXPORTS
	m3	
1968	54,926	7,902
1970	55,082	19,191
1972	62,228	15,946
1974	60,448	18,120

Source: Ministerio de Agricultura
(See Table 13).

TABLE 20: IMPORTATION OF FOREST PRODUCTS BY PERU

	1968	1972	1975
		m ³	
<u>Charcoal</u>	107	6	38
<u>Roundwood</u>			
Conifer	297	12,415	422
Non-Conifer	472	2,934	1,610
Mine Timber	3,597	317	-
Post and Piling	25	-	3,299
<u>Sawn Wood</u>			
Conifer	40,393	42,142	56,043
Non-Conifer	459	99	268
Rail Ties	6,131	174	26,093
Parquet	5	-	781
Veneer	209	1	32
Wood Terziada	756	1,661	511
Laminated Board	43	-	-
Manufactured Wood	1,772	1,912	2,993
Fiber Board	658	567	1,077
<u>TOTAL</u>	<u>54,924</u>	<u>62,228</u>	<u>93,167</u>

Source: Ministerio de Agricultura (See Table 13).

TABLE 21: LOCATION OF FOREST PRODUCTS MILLS BY PRODUCT IN PERU

LOCATION	SAW MILL	PARQUET PLANT	VENEER MILL	LAMINA DORAS	ENCHA PES	PARTICLE BOARD	CAJUNE FAS	PAPER MILL	TOTAL
Piuna	-	7	-	-	-	-	19	-	26
Tumbes	-	4	-	-	-	-	-	-	4
Lambayeque	-	2	-	-	-	-	8	1	11
Chachapoyas	18	-	-	-	-	-	-	-	18
Cajamarca	2	-	-	-	-	-	2	-	4
Jaen	6	6	-	-	-	-	5	-	17
Trujillio	7	-	-	-	-	-	-	2	9
Lima	3	-	-	-	3	-	-	9	15
Iquitos	31	3	2	2	-	-	-	-	38
Pucallpa	45	6	4	-	-	-	-	1*	56
Tarapota	3	-	-	-	-	-	-	-	3
Yurimaguas	4	-	-	-	-	-	-	-	4
Tingo Maria	34	-	-	-	-	1	-	-	35
Moyabama	7	-	-	-	-	-	-	-	7
Huancayo	49	-	-	-	-	-	-	-	49
Oxapampa	12	-	-	-	-	-	11	-	23
San Ramon	16	2	-	-	-	-	11	-	29
Satipo	33	4	-	-	-	-	-	-	37
Villa Rica	20	-	-	-	-	-	10	-	30
Cusco	17	-	-	-	-	-	-	-	17
Puerto	14	-	1	-	-	-	-	-	15
La Convencion	8	-	-	-	-	-	-	-	8
San Gaban	5	-	-	-	-	-	-	-	5
Ayacucho	3	-	-	-	-	-	-	-	3
Apurimac	4	-	-	-	-	-	-	-	4
TOTAL	341	34	7	2	3	1	66	13	467

*Only mill using wood--others use bagasse.

Source: Ministerio de Agricultura (See Table 13).

TABLE 22: AREA, WOOD VOLUME AND ENERGY IN WOOD INVENTORY OF PERUVIAN FORESTS

LAND TYPE	AREA MILLION ha	COMMERCIAL WOOD VOLUME		WOOD BIOMASS ¹ mTONS X 10 ⁶	ENERGY ² JOULES X 10 ¹⁸
		m ³ /ha	TOTAL m ³ X 10 ⁶		
Alluvial Forests					
Class I	3.612	140-180	505.7-650.1	252.8-325.0	4.6-5.9
Class II	7.375	100-130	737.5-958.8	368.7-479.4	6.6-8.6
Class III	5.071	80-100	405.7-507.1	202.8-253.5	3.6-4.6
Hilly Selva Forests					
Class I	12.754	140-180	1,785.6-2,295.7	892.8-1,147.8	16.1-20.7
Class II	16.169	120-150	1,940.3-2,425.4	970.1-1,212.7	17.5-21.8
Class III	9.841	70-120	688.9-1,180.9	344.4-590.4	6.2-10.6
Dry, Dense Forests	0.525	40	21	10.5	0.19
Forests/Savanna	1.121	12-15	13.4-16.8	6.7-8.4	0.12-0.15
Quinual	0.006	20-50	0.12-0.3	0.06-0.15	0.001-0.003
Podocarpus Forests	0.408	70-75	28.6-30.6	14.3-15.3	0.26-0.28
Forests Abandoned from Agriculture	5.191	70	363.4	281.7	5.1
Forests (Inaccessible)	8.667	100-120	866.7-1,040.0	433.3-520.0	7.8-9.4
Forest Plantations	106,140	-	1,143.4	571.7	10.3

Calculated from data in Table 12.

¹ Assumes density of 500 kg/m³.

² Assumes heating value of 18,000 million joules per metric ton.

except in a small area of the extreme north. In this region, forest management should be implemented to sustain the resource base. Plantation management shows promise in much of this region.

In the Sierra, there is considerable opportunity to expand the forest resource. Current estimates predict that 10 million hectares could be forested in this region. Test trials to date show that both eucalyptus and pines will grow rapidly in this region. Establishing such forests here seems urgent since there is land available, an acute need for forest products, excess labor to accomplish the task, and reforestation will help control erosion.

Expanding the forest resource in the Sierra involves certain policy questions. A choice in objectives must be established between targeting plantations only for biofuel or establishing a viable forest products industry with energy opportunities evolving from wastage and non-merchantable trees.

The eucalyptus, which are native to Australia (Peru has over 100,000 ha planted of eucalyptus) emerge as prime candidates for fuel production because of harvesting considerations and since many of these trees can reach a suitable size for harvesting within approximately seven years. Furthermore, some eucalyptus species (number of identifiable species, subspecies, etc. range from approximately 450 to over 700 depending upon the source) (Mariani, 1978) could be grown on marginal land like deserts, swamps, etc. They also have the ability to sprout (coppice) again from their stumps after harvesting, thereby minimizing the requirements for extensive land clearing, cultivation, and replanting operations after each harvest (see Figure 15).

The principal industrial products of eucalyptus are:

- Roundwood - Small poles and large poles for telephone and transmission, minin.
- Sawnwood - Construction timber and flooring, railway sleepers.
- Pulpwood - Hardboard, softboard, and paper.
- Plywood - Laminated wood products.
- Charcoal - Home or restaurant cooking. To be burned in blast-furnaces, in charcoal-iron industries.

Eucalyptus in Australia, South Africa, and other countries are known to provide other valuable minor products (Hall, 1972):

- Honey - Australia exports 17,000 metric tons annually, and
- Essential Oils -- Nearly all species of Eucalyptus have oil producing glands in their leaves which produce oils. The main essential oils and their properties are:
 - Cineol - Used in pharmaceuticals, stain removers.
 - Phellandrene - Used in the industry as a solvent and flotation for metals.
 - Terpineol - Used in perfumery.
 - Eudesmol - Fixative for perfumes.
 - Piperione - Raw material for synthetic thymol and menthol.

Eucalyptus trees can be a good producer of biomass in the Costa, Sierra, and Selva regions of Peru and is an important resource in future forest development.

The dependency of much of the population on concrete and other construction materials that require more energy to produce and process than wood, and the importation of woods (especially softwood pulp and mine timbers) suggest that a viable forest industry would serve the national interest. Such an industry would reduce imports, substitute low energy materials for high energy alternatives, and generate as a byproduct (or in certain cases, the principal raw material) biofuels to meet energy needs. Even in developed countries about 40% of the harvested wood cannot be used for conventional forest products and is diverted to other uses or disposal (increasingly for energy production). Noncommercial trees may also be used for energy wood.

Each hectare of Sierra planted to trees will grow from 10-20 m³/ha/yr during an 18-year growth period. At this rate, 90 to 180 x 10⁹ joules of energy is fixed in merchantable wood (assuming 500 kg/m³ and 18,000 million joules per metric ton of wood). Half of this would probably be waste wood useful for energy production. Should the biomass in noncommercial components be used, the energy from wood could be increased from 15 to 25 percent.

The Selva possesses about 8.7 million hectares (Table 12) needing reforestation following shifting agriculture. Plantations could be established before abandonment and restore the biomass to a useful crop (personal communication, R. Montenegro, FAO Von Humboldt National Forest, Peru).

Currently only 2.7% of the forests are exploited with only an average of 1 m³/ha harvested. The harvest, however, only targets certain prized species (Table 15). Removing only these trees without deliberate attempts to regenerate the choice species will degrade the forest for products. Proper management could both maintain the high productivity and the supply of useful species.

Amazonian forests grow from 10 to 30 m³/ha/yr. If 40 million hectares were deemed accessible for harvests, then 2.7 to 10.8 x 10¹⁸ joules would be produced annually as commercial wood without reducing growing stock. Half of this would be mill waste if processed for forest products and another similar quantity would be potentially available as noncommercial biomass at the harvesting site. Assuming wise management, this annual increment could be maintained or increased. As new technologies for harvesting and transporting are developed, the area for biofuel production could be expanded.

In summary, biofuels from the forest resource appears abundant even if much of the biomass is diverted to forest products (which could replace other energy uses).

V. RESOURCE DEVELOPMENT AND MANAGEMENT

HARVESTING

Harvesting systems are a primary determinant for successful development of forest resources. The best systems to use will vary in Peru because of the diversity of the forests and the terrain supporting them. However, three typical systems now commonly employed are:

1. Axe, hand-rolled with cart hooks and hand winch (most common);
2. Chain saw, cart hook and winch;
3. Chain saw, rubber tire articulated skidder (company extractors).

In the Sierra, harvesting would primarily target plantations of exotic trees planted mainly on deforested lands or lands not in grass and bush. These forests can be harvested and the wood handled largely by hand because of the relatively small tree sizes and well-drained soils. Power saws could be used to advantage in large scale harvests. Fuel wood harvests for domestic use could easily be by hand taking advantage of surplus labor. Access roads would be the principal restraint and care would be needed in siting these and skid-trails to prevent soil erosion during the wet periods.

The Ministry of Agriculture regulates forest harvesting in Peru. The Agricultural VIII zone office in Iquitos, manages about 2,000 contracts with 20 staff members (5 foresters and the remainder technicians). The cutting season here is 6 to 7 months. All-weather logging is not possible and water transport in small creeks is unreliable. Rivers flood 5 to 6 months each year.

The zone office signs contracts with extractors for harvesting six species. Extractors seldom do this since there is little enforcement. Thus, Cedro and Mahogany are usually taken and other species left. Standing wood is usually sold as follows:

Cedro and Mahogany:	500 Soles/m ³
Other Species:	50-70 Soles/m ³ .

Twenty percent of the estimated pay scale is received in advance by extractors. The remainder is payable after scaling the log rafts at the river mill site.

The credit is a serious problem for extractors. The typical credit scheme is as follows:

The Agrarian Bank could make credit available, but does not mainly because extractors lack skill in providing inventories. The absence of credit retards improvement of logging methods.

Also in the Selva, the large size of the trees and the need to liberate harvesting from dependency on river transport suggests a need for mechanical aids to harvesting. This does not preclude the use of hand harvests. The use of wood for biofuels does not recognize current quality constraints. Thus, all species should be useful -- not just those that will float or perform well in current, conventional uses of forest products.

Greater introduction of mechanical felling devices, skidders, loaders, and haulers would allow all trees to be removed and permit year-round operations in many cases. Also, insect and disease decay losses would be eliminated as wood would not be left in the forest awaiting stream-rise. In this way, trees suitable for forest products could be sorted out from those useful only for biofuels.

Proper selection of equipment mixed with other harvesting approaches would take additional study of soils, seasonal site conditions, labor availability, other power systems, the educational level and attitudes of workers, and support systems. The development of appropriate and efficient harvesting systems will be a factor in the utilization of forest resources both for energy production and the forest products industry.

REFORESTATION

Currently, the forestry law in Peru requires extractors to plant two trees for each m³ extracted. There is little enforcement, nor do the extractors know where, when, and how to plant. Further, the Forestry Department has only one nursery for the entire Loreto zone in the Selva (50 million ha). However, to ensure the future productivity of forest resources, adequate reforestation is necessary.

Tree planting or artificial forestation with eucalyptus and/or pinus seems to be the only reasonable alternative in the Sierra. Considerable attention needs to be given to pre-planting site preparation. Brush removal and perhaps the use of terraces to stabilize hillsides may prove to be important to the establishment and early growth of plantings. A nursery

support system would need to be established in a network proximal to the reforestation areas. Nursery production techniques worldwide are well advanced and the technology easily transferable (see Figure 16).

Many trials of different species have been conducted in Peru. From these, Eucalyptus globulus and Pinus radiata appear well suited to local conditions. Additional tests, however, appear desirable to ascertain the best species for the variety of growth sites available (see Figure 17).

In general, Eucalyptus displays growth superior to other species. Undoubtedly, this tree will meet many domestic needs for sawn timber and fuelwood. But it will not help Peru's need for a softwood resource to supply pulp for paper manufacturers. Pinus radiata or P. caribaea, oocarpa, pinasta, eldarica or others may prove useful if a softwood production goal is set. Pinus radiata performance to date suggests that it will grow quite well on many sites in the Sierra.

The advantage of Eucalyptus besides rapid growth is its capacity to coppice. Pines do not coppice. A disadvantage of Eucalyptus, however, is the lack of growth of grasses and other forage species underneath the canopies of these trees. Because of the need to provide forage for domestic animals, pines may often prove desirable because multiple use is possible.

For either species, soils needs to be matched with species requirements to make sure that each hectare produces up to its biomass potential. Soil surveys and species tests on each major soil association need completion before extensive plantings are begun. Soil chemical, physical, and biological properties will determine the success of the species planted.

In the Selva, a number of reforestation opportunities are available. Immediate results by artificial reforestation could be realized in areas abandoned after shifting agriculture. Although the feasibility of this practice has been demonstrated, the best species, spacing, and subsequent management practices have not been fully investigated. Whereas numerous species trials have been conducted in the Sierra, few have been done in the Selva. There are Eucalyptus and Pinus species potentially suited to these wetter conditions. In addition, other exotics (e.g., Gmelina) and several native species may prove useful for this purpose.

Figure 16: Experimental Nursery Operation for the Production of Eucalyptus and Pinus Radiata of the National Technical University at Cajamarca.

Figure 17: Experimental Plantation of Eucalyptus and Pinus Radiata Operated by the National Technical University at Cajamarca.

In certain sites of the Selva, where all commercially useful trees have been harvested, reforestation is urgently needed. For example, the wood resource along the river near Iquitos is depleted of commercial species. However, because of species utilization changes since this area was first logged, "Lupuna", a tree not previously used, today is available in some places and is a prized specie for plywood. In most cases, the desired species will not reestablish under the shade of the remaining "cull" trees. Developing a demand for woody biofuels would create a market for these cull trees and the needed impetus to reforest these sites. One method showing promise is preliminary trials on the Von Humboldt National Forest strip removal of all trees, planting with choice native species and cleaning for two years. The cleaning operations (mechanical or chemical) are necessary to allow the planted trees to get their crowns above the competing vegetation.

Another alternative may involve cutting all residual trees, using them for biofuels, site preparation by scarification, and then establishing plantations. Mechanical preparation must be done carefully to prevent site quality deterioration from topsoil removal and from the loss of nutrients stored in tree foliage and twigs remaining from harvest.

Natural regeneration by using standard silviculture systems such as selection cutting, shelterwood, strip cutting, etc. may prove useful but needs extensive investigation before one or more systems are selected. A wise choice, properly implemented, however, could assure the sustained productivity of these forest lands and their immense growth capacities. A serious restraint is the worldwide lack of knowledge on silviculture systems suitable for the tropics.

TRAINING

Achieving the objectives outlined above will require preparation through education and training of a larger supply of professionals and para-professionals to support forest resource development activities. Wood, unlike fossil fuels, should never run out if the forests are managed properly.

Expanded use of wood as a principal building material in Peru will make the housing industry less dependent upon fossil energy but will require

the introduction of this notion into Peruvian culture. The population has a heritage of using clays for adobe and identity with concrete and masonry was easily achieved because of their similarity to adobe. Woodworking, however, is not so well-developed. Public education on the value of using wood needs advocacy and woodworking skills taught to encourage its use. In this way, Peru could take advantage of one of its most abundant resources, reduce the needs for energy-intensive materials, and aid the development of a viable forest industry.

For a highly professional cadre of forest managers, a number of disciplines need to be educated and these brought to bear on the Peruvian forest resource. Silviculturists with competencies in the area of species ecology, soils and nutrition, genetic selection and breeding, and nursery management are needed. Protection specialists are needed to keep pests under surveillance and to promote fire as a management tool and to prevent wildfires.

Utilization specialists are needed to expand the use of the many under-utilized species. They need to develop quality grades and standards to protect the consumers from inferior products and to develop means of seasoning and processing woods to meet these standards. Testing of woods to assure their proper performance in the selected use is essential.

Forest engineers are needed to develop harvesting and other forest operations that are most economical but environmentally acceptable. These studies should be complimented with consideration of the attitudes and aptitudes of the forest labor pool.

For the Selva, forest ecologists keenly sensitive to the problems unique to this region are urgently needed. It appears that most forestry professionals in Peru are educated in the Costa and have limited tropical forestry experience. These ecosystems are very productive, but also very fragile and sensitive to disturbance.

ENVIRONMENTAL FACTORS

The major environmental factors associated with land use in Peru mainly pertains to soil and water. Intimately tied to these are nutrients. Forest cover mediates the effects of climate and weather events such that

forest removal or establishment can sharply change ambient conditions and affect water behavior and soil properties.

Lands affected mainly by grazing (e.g., the Sierra) receive intense solar radiation that causes the surface soil temperature to be high and nutrient mineralization to be rapid. Over-grazing can reduce the infiltration rate of water with runoff resulting. Establishing a forest canopy will reduce soil temperature and restore desirable hydrologic functions involving infiltration and percolation. In addition, rain-drop energy is lessened and erosion reduced. Once fully stocked with trees, evapotranspiration probably will be increased. This will increase the soil storage of water and level out the storm hydrograph in streams associated with the watershed.

Stream water level can be regulated by controlling the proportion of the lands in the harvested, recently generated, and fully stocked condition.

Excessive erosion proceeds only when there is no crop canopy. Thus, management schemes need to be devised to minimize erosion and to be properly phased with appropriate climatic events. Forests are nutrient conservers as they filter atmospheric depositions and store nutrients in their biomass. Since only the woody component is used, proper management of the logging slash is essential to prevent nutrient losses. For example, excessively hot fires in the dry season could have serious effects on soil conditions, and nutrient and water losses.

Roads and skid-trails used in harvest must be properly sited and constructed to minimize erosion. Contour roads could serve somewhat like terraces to increase infiltration of water.

In the Selva, a different family of problems are present although they relate to the same key factors. Humid, tropical forests differ from temperate forest ecosystems by most of the nutrients being contained in the biological material. This phenomenon has been exploited for generations in these regions by shifting agriculture -- felling of trees and burning the vegetation to release the nutrients so that crop production is possible (see Figure 18). After a few crop years, the area is allowed to grow back to native vegetation before repeating the process. Erosion is a problem only when the soil is bare. Wise practitioners of this form of agriculture keep bare soil intervals to a minimum. Where such practices have not been

Figure 18. Shifting Agricultural Practices in the Selva (Forepart of clearing contains drying trees, back part of clearing has been burned).

Figure 19. Mechanically Harvested Site in the Selva Tropical Forest

followed, erosion (as much as 150 t/ha/yr) of soil, has been severe. Losses of 2-3 cm of topsoil can cause yield reductions of 50 percent.

Forest removal and cropping results in:

1. Reduced infiltration
2. Accelerated organic matter decomposition
3. Increased bulk density
4. Increased soil nutrients (temporary)
5. Increased surface water flow

When forest regrowth is permitted, after crop yields decline, these trends are reversed and the soil ameliorated. Allowing forest regrowth also keeps pest populations that develop on monocultures from reaching serious levels.

Site preparation can be associated with serious problems (see Figure 19). In areas too wet for burning, bulldozing can reduce soil productivity by compaction, topsoil removal, and removal of nutrients contained in the slash from felled trees. Infiltration is reduced dramatically with mechanical disturbance and erosion accelerated. Where possible, the felled material should be viewed as a mulch for the new forest. In areas seasonally dry, proper timing of felling, burning, and piling of debris can be done mechanically without serious adverse impacts. Soil moisture contents during the period of activity should be chosen when puddling and compaction are not problems.

The object of any reforestation scheme should be to get the new forest reestablished as quickly as possible and keep the period of exposed soil as short as possible. In this way, environmental problems will be prevented and forest growth assured. From comprehensive reviews of cropping systems in the tropics, growing trees (e.g., forest, nut, or rubber) seem to be a feasible alternative for these lands if processing facilities for the crop are nearby.

Woody waste is now burned or dumped in the countryside or rivers. Air and water pollution may result from these operations. Creating a use for these materials could go far in alleviating problems associated with this disposal procedure.

INTEGRATED UTILIZATION

Developing forest biofuel cropping systems which are compatible with other needs of the people can have positive benefits to the development of this energy resource. Public acceptance is essential.

First, the virtues of a renewable energy supply must be advocated. Secondly, choosing forest cropping that is compatible with other human needs must be demonstrated. For example, acceptance would be high in the Sierra if forests for fuel can be interfaced with grazing opportunities on the land. Where this is desirable, pines will probably be the species of choice. Also, these forests must be managed to assure the supply of high quality water, often a limiting resource in the Sierra.

In the Selva, forest production in many cases must be integrated into a multicropping scheme. A diverse flora will reduce pests and also produce a variety of other commodities. Rotation with annual crops, grazing crops, and periodic reforestation could prove economically and environmentally acceptable.

In areas not intended for agricultural production, harvesting of the forest should be done applying similar principles. Clear-cut harvest areas should be sized to prevent excessive water loss and erosion. Where strip cutting is employed, clearing by environmentally acceptable chemicals may prove useful if hand labor is not available. Where selection cutting is employed (that is, removing certain large trees for timber products, cull trees for energy), an ample number of young trees of desirable species must be left and protected.

These considerations recognize that certain forests cannot be harvested for any purpose because of terrain (too steep), soil (too erosive), and utilization restraints (mills too remote).

Knowledge of soil, site, and species requirements and the interactions of management practices with these and climatic events can assure productive use of the land without adverse environmental problems.

VI. MARKET CONSIDERATIONS

IMPORTATION

Importation of agricultural and forestry commodities into Peru significantly affect the development of biomass resources for energy production. For example, in 1975 over 90% of the internal demand for oats, over 35% of the internal demand for corn, over 85% of the internal demand for wheat, and over 95% of the internal demand for soybeans had to be satisfied by imports (OSEI, 1975). In 1975, a deficit in agricultural trade of \$12 million occurred and increased to \$33 million in 1976 because of a drop in world sugar prices. Importation of wood in 1972 was 62,228 m³ of which 87% was coniferous wood (FAO, 1977). Most of Peru's forest resources are hardwood and importation of softwood can be expected to continue in the future.

Until significant increases in agricultural productivity are realized, especially in cereal crop production, governmental emphasis in resource development can be expected to remain on food production. This position is entirely justified. The 1976 total agriculture production index was 103 (1961-1965 production equals 100); the 1976 total food production index was 119 (USDA, 1977). This gives an average annual increase for total agricultural production indices between 1965 and 1976 of only .3% while that for the food production indices was 1.6%. On a per capita basis, the situation is less encouraging. The 1976 per capita index for total agricultural production was down to 70 and that for total food production to 81. Between 1965 and 1976, this amounts to an average annual decrease for per capita agricultural production indices of 3.2% and a decrease for per capita food production indices of 1.9%. The situation over the past few years has begun to stabilize. The total food production indices has begun to increase at a rate between 3-4% per year, roughly the same as the population growth, and as a consequence, the per capita food production index has remained at 81 for several years. However, overall agricultural production has not increased as rapidly resulting in lower per capita indices. Development of biomass resources energy must be incorporated into the overall development of food and agriculture in Peru. Some basic strategies for Peruvian agricultural development were identified in a 1971 study jointly undertaken by the

Peruvian Ministry of Agriculture and the U.S. Agency for International Development. These approaches and new ones which have since been identified, need to be related to plans for energy development overall and biofuel development in particular.

With forest products, Peru is also a net importer. On the average, 280% more forest products were imported than exported between 1968 and 1974 (see Table 19). As stated previously, much of the importation is a result of little softwood in the Peruvian forests. However, the importation of processed materials indicates a need for expanding production for internal markets by the forest industries sector. The import situation points out that increased attention should be given to development of softwood resources and to expansion of wood processing capabilities.

MARKET DEVELOPMENT - INTERNAL

Housing construction in Peru has made use principally of adobe-type materials later replaced by steel reinforced concrete. This resulted because early settlements were in areas without forests as the Costa or the valleys of the Sierra. In the Selva, which was sparsely populated, palm thatch was used for housing; thus, wood housing has not become an integral part of Peruvian culture.

As a result, energy intensive materials such as cement and steel are used for housing. Considerable energy could be conserved if the vast wood resources were used for home and other building construction projects. A requisite is the development of markets for wood by developing domestic uses. New products can increase the wood utilization in the manufacture of inorganic bound wood-cement boards. These boards are termite, weather and fire resistant, and could be used in wood framed houses. Wood waste in the manufacturing of inorganic bound wood-cement boards could be converted to biomass fuels and used in the cement plant to reduce petroleum derived fuel consumption.

MARKET DEVELOPMENT - EXTERNAL

With the second largest forestry resources in South America, Peru can be a significant world exporter of forest products. Peru is exporting plywood panels and veneers to North America and European markets (FAO,

1976). However, based upon trends in other parts of South America and in the world as a whole, the market share of plywood may decline well into the 1980's. To protect and expand its current share of the world market, Peru should vigorously develop and expand its internal wood processing capabilities. The manufacturing of inorganic bound wood-cement boards mentioned above could develop new markets and be exported to neighboring countries (e.g., Bolivia, Brazil, Chile, etc.). Thus, expansion of Peruvian forest product industries is essential for both internal and external market development.

MANPOWER

Wood in Peru is abundant, the energy cost in producing wood is low relative to alternatives; thus, this avenue needs to be advocated and the skills for working wood need to be developed among the people. Wood, unlike fossil fuels, is renewable and can be an inexhaustible resource if managed properly.

Forestry activity and wood working (i.e., saw mills, plywood plants, etc.) could be labor-intensive operations. Mills and plants would be located in the rural areas near the resource base. Increasing employment opportunities here will help stem the urban drift of the workers. However, housing, schools, medical care, etc. should concurrently also be developed with this industrial base. The extent of the impact of expansion of the forest products industry on national unemployment shall depend upon the degree to which both the internal and external markets for forest products are developed.

Coordination between forestry operations (i.e., harvesting, forest products manufacturing) and agricultural operations could improve manpower utilization to avoid creating a critical shortage or an over-supply during the wet and dry seasons. Forest operations, if well managed, could provide jobs all year around, cash crops, and livelihood to the local population (Mariani, 1978), thereby, lessening the drift of the workers from the country to heavily populated areas like Lima.

Presently, forestry professionals are educated without much experience of familiarity with the humid tropics where the forest resource and growth potential occurs. Most resource professionals are educated in the Costa

without extensive exposure to the productive forest region of Peru. More contact between field and university personnel can enhance forest management approaches.

The absence of electricity in the majority of isolated rural villages also aggravates the population drift. It is practically impossible to develop saw mills, carpentry shops, maintenance shops, etc., without electrical supply. Difficulties in providing minimum education facilities for grown-ups is another consequence of the lack of electricity (Indacochea, 1978). Biomass derived petroleum substitutes could generate the required electricity economically, profitably, and at the same time, improve the socio-economical systems in the rural areas. The forest or agricultural waste to produce biofuels should be available without damaging the environment, forestry, or agricultural systems.

ENERGY POLICY AND PRICING

Current governmental pricing and regulatory policies are sometimes counter-productive for expanding biofuel utilization. The primary substitute for firewood, dung, etc. is kerosene, which is heavily subsidized. The retail price of kerosene ranges from 17 S/per gallon in Lima to 16 S/gallon in Tarapoto. This is about 9 cents/gallon at an exchange rate of 180S/per dollar. The world market price is approximately 30 cents/gallon. A similar situation for diesel exists to a lesser extent. The price of diesel in Tarapoto is 32 S/ or about 18 cents per gallon delivered to Electroperu (Poole, 1978). Such subsidies may be justifiable and the kerosene subsidy seems politically motivated. However, the impact of such pricing policies creates a situation where firewood purchased for cooking is more costly than kerosene in many parts of the Selva and Sierra. Careful consideration needs to be given to the consequences of energy pricing policies and biofuel development.

Another governmental energy policy makes charcoal production illegal, which obviously complicates programs to develop production of this promising biofuel option. Officially, charcoal production should not occur; however, an expansion of production appears to be occurring in the Sierra. With regard to bagasse, the official policy is to increase its utilization.

Competing energy development approaches for electrical generation from biofuel or small scale hydroelectric could arise in the future. The High Sierra seems to be a region where such conflicts could readily occur.

Uncertainty regarding future oil production can also complicate decision-making on biofuel development. Peru, which is now a net exporter, may have to import oil in the future which would significantly affect energy pricing throughout the country. With the variety of energy policies and alternatives present, biofuel development should, to the extent possible, be integrated more into the governmental decision-making on energy policy.

TRANSPORTATION

Transporting forest resources from the source of supply to the site of utilization is a serious problem at all levels of distribution. The collection and transportation of firewood by the rural population in the Sierra region consumes considerable time and effort. Typically, firewood is collected and carried home by the people themselves (see Figure 20). Distances of 20 kilometers are not uncommon for persons to carry firewood. This level of effort for persons whose diet may be marginally sufficient causes great physical stress. Biomass energy strategies for Peru should consider approaches that would alleviate the collection and transportation problems of individuals using biofuels.

On a macrolevel, transportation is a limiting factor in forest resource development. The Andes Mountains create a massive barrier for the transportation of Selva forest products to Costa markets. Within the Selva, transporting the wood from deep in the forest to the mills is a considerable problem. Novel approaches such as the construction of a floating mobile plywood plant (see Figure 21) offer promising solutions. However, lack of adequate transportation may be the most significant factor governing the development of biofuel resources in Peru.

Figure 20: Firewood Being Transported Home in the Sierra (Photo Courtesy of R. Giesecke, Member Peruvian Energy Assessment Team.)

Figure 21: Floating Plywood Plants Waiting to be Conveyed to Forest Harvesting Site on the Amazon River.

VII. BIOFUEL TECHNOLOGY OPTIONS

DESCRIPTION OF CURRENT TECHNOLOGIES

Current approaches to biomass conversion can be categorized as thermal, thermo-chemical, chemical, or biological. Of these, the thermal approach is the most straight-forward and simply involves the direct combustion or incineration of biomass for the generation of heat. If combustion occurs in a specially designed boiler, as used in the sugar processing industry, pressurized steam can be generated from the heat. With steam turbines, the pressurized steam can generate electricity and then serve as a source of process heat. Mechanical energy can also be produced if a steam engine is used in place of a turbine. A simpler approach involves the incineration of biomass to produce process heat for direct industrial application, such as cotton drying or crop drying.

Thermochemical conversion approaches are typically a combination of pyrolytic and combustion processes. Pyrolysis is the thermochemical alteration of organic matter in agricultural and forestry residues in the absence of air. The first material pyrolyzed by man most likely was wood and the end-use energy produced was charcoal, a cleaner burning fuel. This is an ancient and simple approach to pyrolysis, but is still one of the most practiced biomass conversion strategies in the world today. Brazil has an intensive national program to increase charcoal production and today 40% of the energy needs of Brazilian steel industry (approximately 2 million tons annually) are supplied by charcoal (Goldemberg, 1978).

Pyrolysis also produces other forms of energy aside from the carbonized char described above. This conversion process can produce an oil-like substance known as pyrolytic oil and a low-to-medium BTU combustible gas. The quantity of char, oil, or gas produced depends primarily on the chemical composition of the feed, its preparation, the reaction temperatures, the reaction pressure, and the residence time of the material in the reactor (ERDA, 1977).

Chemical approaches involve acid hydrolysis or the use of other chemicals to extract particular organic materials from biomass which can be used in place of petroleum derived compounds. Typical products obtained from this approach include oils, resins, and other assorted organics. Perhaps the most industrially important of these is furfural.

Furfural was identified in 1832 by Dobereiner and it is an aldehyde with the $-CHO$ group in the α position. Its production was commercialized by Quaker Oats in 1922 and it is obtained from pentosan containing agricultural residues. Primarily it serves as a chemical intermediate for the production of furfuryl alcohol, tetrahydrofurfuryl alcohol, furan, tetrahydrofuran, polytetramethylene ether glycol, or as a precursor of pyrrole, pyrrolidine, these products have many important applications. The use of furfural as a selective solvent in the refining of lubricating oils to increase their stability during processing; as an extractive distillation medium in the manufacture of butadiene from petroleum; as a decolorizing agent for wood resin; and as a resin former are some such applications.

Biological conversions of biomass offer numerous avenues for the production of biofuels. The biofuels produced are either liquid or gaseous as a result of the biochemical alteration of the substrate during the metabolism of a microorganism. The two biological conversion processes most practiced are the fermentation of carbohydrates to produce ethanol and the anaerobic digestion of organic matter to produce a methane containing gas.

Fermentation is essentially a hydrolytic process. Beginning with one six carbon sugar molecule (glucose), the enzymes produced by facultative microorganisms (usually a yeast known as Saccharomyces cerevisiae), sequentially breakdown the sugar molecule into two molecules of ethanol and two molecules of carbon dioxide. In addition, the microorganism obtains metabolic energy from the biochemical hydrolysis of the sugar. This process has been employed by people throughout the centuries to produce fermented beverages.

A process diagram (Figure 22) has been developed for the industrial production of ethanol from molasses using various references on industrial ethanol production. The first phase of the process involves the dilution of the molasses and adjusting the pH. Other nutrients are not usually required if blackstrap molasses is used because it contains non-sugar

nutrients. The mash (as the acidified diluted molasses is called) is now transferred to the fermentation vat.

Upon inoculation with yeast, fermentation begins and continues for 28 to 72 hours (average 45 hours) and results in an alcohol concentration between 6-10%. The optimum temperature varies between 25° and 35°C. During fermentation carbon dioxide gas is produced in equimolar quantities with ethanol. The fermentation liquor is now centrifuged and a yeast-rich stream is separated out. Part of the yeast will be returned to the yeast vat for reuse; the majority will be dried and sold.

The light stream from the centrifuge is passed through a heat exchange and into the still. Overhead from this still is passed through a condenser and the condensate contains 60% ethanol and a mixture of aldehydes.

The condensate is then charged into the aldehyde column where these and other highly volatile compounds are boiled off. The ethanol fraction comes off after the aldehyde one and then enters the rectifying column. The lower fraction is known as fusel oil which is a complex mixture of higher alcohols. Water known as Lutter water leaves the system from the bottom of the column.

The final step in the process is the production of anhydrous (water free) ethanol. To achieve this product, benzene is added (10 times the quantity of water present) and a binary system of ethanol-benzene is formed which will distill until essentially all the benzene is exhausted. Typically, for each ton of molasses (with a 55% sugar content) fermented, 68 gallons of ethanol, 340 lbs of CO₂, 1.02 lbs of yeasts, 1.6 lbs of fusel oil, and 435 lbs of stillage can be expected to be produced.

Another commonly practiced biological conversion process is anaerobic digestion. Anaerobic degradation of organic matter for the production of methane involves three general groups of interacting bacteria. The first operates on cellulosidic wastes to produce organic acids, alcohols, H₂, CO₂, NH₃, and sulfide; the second oxidizes the longer chain organic acids to acetate and H₂; and the third utilizes the H₂ and CO₂ and acetate to produce methane (Bryant, 1976). Temperature greatly affects the rate of conversion. For optimum production, the temperature of the reactor should be kept between 33°-38°C. To assure stability of the process, sudden temperature changes should be avoided.

This technology has been very successfully adapted to conditions in developing countries. A typical design for a small anaerobic unit is pictured in Figure 23. The quantities of biogas required for specific applications are given in Table 23.

PERUVIAN BIOFUEL TECHNOLOGY OPTIONS

As previously mentioned, Peru has extensive and diverse agricultural and forestry resources. As a result of the meetings among Peruvian and U.S. biofuel team members after the in-country assessment, the following biofuel technological approaches were identified as promising options.

OPTION A: SMALL TO MEDIUM SCALE GASIFICATION

The cooperative U.S.-Peru development and demonstration of small to medium scale gasification systems to produce low-BTU gas from the pyrolysis of biomass is a promising venture. Such systems could power various types of machinery (e.g., diesel generators, irrigation pump, etc.) and provide a substitute for petroleum derived fuels. Proposed projects would adapt existing technology to local conditions and identify potential application and feasibility through demonstration projects.

OPTION B: WOOD WASTE INVENTORY

Most estimates fix the processing plant waste wood production at about 50 percent of the wood delivered to the mill. In Peru there are 230 sawmills, 8 plywood and veneer plants, and several other plants that produce pulp and paper, particle board, and flaving. However, logging slash residues and non-commercial tree residues are estimable by the crudest of techniques. Quantitative biomass inventories need to be made to better assess these biofuel resources. Such a study would require destructive sampling and determination of areal weights and its distribution among tree species and among components of the trees. These inventories should be done across the array of land productivity classes within each physiographic region and major soil associations within each region. With these data in hand, precise appraisals of woody biomass supply for energy uses would be possible. Investments in biofuel utilization opportunities can be planned properly only when the resource supply can be accurately appraised.

Proposed projects would undertake an extensive survey of wasted or unutilized forest residues, generated by agricultural, forestry, or industrial activity, which could provide low-cost and readily available sources of biomass for energy conversion.

OPTION C: STATIONARY AND MOBILE CHARCOAL PRODUCTION SYSTEMS

Assessment of the potential of using mobile (i.e., tractor mounted or rail-mounted) charcoal kilns for the production of charcoal at the forest harvesting site is a promising biofuel technological option. The development of such a system would allow for the greater utilization of forestry wastes and non-commercial wood species by mitigating the transportation problems associated with shipping biomass to a conversion site, as well as the production of a valuable fuel resource. Similarly, stationary sites would permit conversion of biomass residues at forest and agricultural processing sites. A small scale objective for increasing charcoal production is the substitution of kerosene used for cooking by charcoal in rural, small urban, and secondary cities. A large scale objective is the substitution of imported metallurgical coals by charcoal. Proposed project would develop small scale systems (both mobile and stationary) for charcoal production for cooking or other domestic or industrial uses.

OPTION D: WOOD DISTILLATION

The destructive distillation of surplus and waste wood in Peru appeared to be an attractive option. The destructive distillation it is capable of producing is methanol, cresote, acetone, tar, and charcoal. These by-products offered certain definitive advantages in the national economy mainly because it could substitute oil that could be sold to the international market and obtain foreign exchange. A feasibility study should determine the practicality of implementation of such wood distillation system in Peru. The needs for charcoal resource has been identified for the iron-industry in Chimpote area. Proposed effort would adapt existing technology for a pilot plant demonstration of the process and provide market penetration studies.

OPTION E: FOREST RESOURCE DEVELOPMENT, MANAGEMENT, AND UTILIZATION

Forest biomass can provide massive amounts of biofuels for Peru while also generating export commodities and reducing imports. Forest management in the tropics in both humid and seasonably humid regions where bio-production potentials are great is grossly inadequate. Tropical ecosystems are fragile and sensitive to disturbance. Examples of catastrophic results in other countries document the results of improper management. Reforestation and the introduction and culture of exotic species are similarly advanced in other countries lacking a softwood resource and relying on forest products for both energy and economic values. A broad based forest resource program needs to be developed which emphasizes:

1. Reforestation and management of the humid tropical forests following harvests removals and soil-site specificity of management practices.
2. Determine properties for all tropical woods, how to group them in utilization classes, establish grades and standards, and develop uses especially in housing to reduce the depending on energy intensive alternatives such as concrete and metallic structures.
3. Evaluate potential species and their site requirements for forestation of idle lands in the Sierra. Introduce genetic solution, cultural practices, and integrate management for forest, range, and wild animals values. Eucalyptus and Pinus species could be used for forestation of about 10 million hectares where lands are underused, a labor surplus exists, and energy needs are great.
4. Develop and expand the utilization of forest products in Peru, especially in the construction industry.

The experience and success for forest management and the wood products industry in the United States provides a sound basis for U.S.-Peru cooperation in the development of the above program. Proposed project would: 1) identify and develop effective forestry management programs, 2) identify and initiate forestry development projects, 3) identify, develop, and initiate training programs in forest management, 4) develop new uses for forest products, and 5) train individuals in woodworking.

OPTION F: ELECTRICAL COGENERATION

Plywood and milling operations in Peru can provide a site for the demonstration of system for conservation of electricity and process steam currently practiced by the U.S. forest industry. Also, an evaluation should be undertaken to assess the energy plantation concept to provide biofuels for the generation of electricity and process heat for small towns in the Selva. The feasibility study should determine the practicality of using locally available wood for firing the steam boiler and should assess whether this form of renewable source of energy could make an important contribution to Peru's energy consumption in future years. Proposed projects would adapt existing technology (wood-fired steam boiler design) and provide small scale electrical generation (.5-2 MW) and process steam for local uses to be defined.

OPTION G: CHEMICAL PRODUCTION AND MARKET PENETRATION

Assess and evaluate resource and economic factors relevant to the development of industrial chemical technologies (e.g., furfural production) which utilized biomass as the primary material input. The development of a pilot plant would provide the appropriate vehicle to accomplish such as assessment of industrial solvents and chemical intermediates derived from biomass for Peruvian consumption. Market penetration studies would identify the potential of a national effort to develop this resource for use by both internal and external markets.

OPTION H: ANAEROBIC DIGESTION TECHNOLOGY

The development of anaerobic digestion systems for rural Peruvian situations and possibly urban application would be undertaken. The construction and field testing of the model system would then follow. An assessment of strategies for introducing such systems for home use in rural Peru and the training of personnel in the construction and operation of the units would be done.

OPTION I: DEVELOPMENT OF ETHANOL PRODUCTION CAPABILITIES

Expansion of ethanol production in Peru is a viable biofuel approach. The ethanol could be used to provide fuel for transportation, cooking, and

other industrial uses. Alternatives for recovering and utilizing the fermentation by-products, such as CO₂, yeast, fusel oil, stillage, etc. would also be identified and appraised. Such projects could assess the feasibility and of options for increasing ethanol production at existing fermentation plants and initiate a research and development program to explore the use of other biomass resources (e.g., potatoe, yuca (cassava)) as substrates for fermentation and recovering and utilizing by-products of the process.

OPTION J: AGRICULTURAL STRATEGIES FOR FUEL PRODUCTION

The ultimate objective of agricultural production in Peru will remain on increasing food production in the foreseeable future. However, certain agricultural strategies could be initiated which could increase the availability of agricultural residues, or perhaps even whole crops, for energy production. One such strategy is the increased practice of multiple cropping. This approach could be primarily utilized for increasing both the production of agricultural residues for energy conversion. Another possible alternative is the utilization of marginal lands for the production of agricultural fuels. Such strategies need to be further assessed.

VIII. POTENTIAL REGIONAL APPLICATIONS

Each of the biofuel technology options described in Chapter VII have particular regional applications because of differences in vegetation, climate, industrial capabilities, and so forth. The Costa Region has its own particular set of applications which will be defined by the following set of options, as do the Sierra and Selva.

COSTA REGION

COSTA OPTION A-I: GASIFIER POWERED IRRIGATION SYSTEMS

Utilize agricultural residue, particularly, sugarcane field residue to fuel gasifier for the production of a low Btu gas to power an irrigation pump.

COSTA OPTION E-I: EUCALYPTUS PLANTATION DEVELOPMENT

Eucalyptus plantations in the Costa could be a potential source of firewood, charcoal, and waste wood to feed small-scale gasifiers to produce electricity or biofuel to use in the water pumping engines on the coastal irrigation projects that are heavy users of gasoline or fuel oil.

COSTA OPTION F-I: EXPANDED COGENERATION FROM FIELD RESIDUES

Cogeneration from the burning of bagasse is commonly practiced at sugar processing plants, bagasse could be substituted or electrical generation expanded if field residue could be employed.

COSTA OPTION G-I: DEVELOPMENT OF FURFURAL PRODUCTION

Bagasse, rice hulls, corn cobs, or other pentosan containing residues are available in the Costa Region and could be used for feedstock for the production of furfural if processing facilities were constructed.

COSTA OPTION H-I: RURAL ANAEROBIC DIGESTER DEVELOPMENT

Livestock manures produced by animals in farms in the Costa Region could be used to produce methane for on the farm use if such systems were available.

COSTA OPTION H-II: ANAEROBIC MUNICIPAL WASTE TREATMENT

The construction of anaerobic digester for the treatment of municipal sewage for the major coastal cities could provide both waste treatment and methane.

COSTA OPTION I-1: INCREASED ETHANOL PRODUCTION

Use of wastes from brewery wastes to produce more ethanol or increased utilization of molasses or bagasse could increase ethanol production.

COSTA OPTION I-II: RECOVERY AND UTILIZATION OF FERMENTATION BY-PRODUCTS

A near-term potential of saving 40,000 barrels of diesel annually in the Lima area could be realized if a system to liquify the carbon dioxide CO₂ that is discharged to the atmosphere by fermentation were recovered to replace the manufactured carbon dioxide that presently is made from fossil fuel feedstock. The manufactured CO₂ presently is utilized in the fabrication of dry ice and beverages. Sugar mills are sincerely interested in selling other by-products from the fermentation that are now being wasted.

COSTA OPTION J-I: ASSESSMENT OF MULTIPLE CROPPING STRATEGIES

The overall agricultural productivity of the Costa could be increased by the introduction of multiple cropping approaches. The applicability of such practices being employed to increase residue availability for energy conversion should be assessed and strategies developed for its introduction.

SIERRA REGION

SIERRA OPTION A-I: SMALL-SCALE GASIFIER DEVELOPMENT

The development of small-scale gasifier units to power machinery or generators is a viable biofuel option for the utilization of crop residues in this area.

SIERRA OPTION C-I: PLANTATION FOR CHARCOAL PRODUCTION

The possibility of developing Eucalyptus plantations for the production of charcoal for home and other other commercial uses is an alternative.

SIERRA OPTION E-I: PLANTATION DEVELOPMENT

An additional 10 million hectares of land in the Sierra could support either Eucalyptus or Pine plantations. The development of such plantations would not only make firewood more available, but would help control erosion and stimulate the development of local wood product industries.

SIERRA OPTION E-II: WOOD FRAME CONSTRUCTION

Wood frame construction will permit the incorporation of passive solar systems (e.g., better insulation, etc.) in new construction. Wood is by far the lowest energy user in converting the raw construction material into a finished product. With Eucalyptus as a source of wood, the opportunities for an additional cash crop and employment for the local population make introduction of wood frame construction in Peru a viable option.

SIERRA OPTION F-I: COGENERATION

For many years, Eucalyptus have been planted in the Sierra, particularly in mining areas. The Eucalyptus wood was used as structural members in the mining tunnels. These Eucalyptus plantations should be expanded to produce wood that could be used to generate electricity or for water heating. At present at the Buenaventura mines, 1.5 million gallons of diesel are used annually to generate 4,000 KW/hr (Teegan, 1978). Biofuel could contribute in substantial saving of this fossil fuel.

The Cusco area could benefit by large plantations of Eucalyptus trees. Evidence of good growth of *E. globulus* can be seen on the mountainous area and along the Urubamba River Valley. Shortages of electricity were observed during our investigative trip in this area. Such electrical deficiency could curtail the construction of hotel accommodations that are badly needed on one of the most visited spots of the World.

Tourism is another important source of foreign exchange, and biofuel could contribute to its development if Eucalyptus plantations are established 20 kilometers from Machupicchu where are flat land, water, and manpower. The existing railroad could be used to transport the wood or charcoal for electrical generation at the end of the railroad. These are considerations only. At present, enough Eucalyptus are planted to generate 1,000 KW/hr.

SIERRA OPTION H-I: RURAL ANAEROBIC DIGESTER

The introduction of small scale anaerobic digesters into the Sierra would provide an alternative to the utilization of dung as a fuel. The fuel produced would be clean burning and could also provide lighting.

SIERRA OPTION I-1: POTATO FERMENTATION

The feasibility and practicality of using potatoes as a feedstock for fermentation and ethanol production should be addressed. The development of such an industry could provide an expanded and stabilized market for the potato in Peru.

SIERRA OPTION J-I: CHENOPODIUM SEEDING

Consideration should be given to promoting the seeding of Chenopodium Quinoa in areas above the treeline in the Sierra. This material could provide food grain in addition to residue which would be a readily accessible fuel.

SELVA REGION

SELVA OPTION A-I: GASIFICATION FOR ELECTRICAL GENERATION

In areas of the Selva, as Tarapoto, sufficient forest resources are present to supply a gasifier which could power the town's 2 megawatt power plant. The use of waste wood from land clearing in the area could provide an inexpensive source of fuel for the gasifier and be compatible with agricultural development.

SELVA OPTION B-I: WOOD WASTE INVENTORY

There exists a serious need to identify the amount of wood waste generated at forest harvesting sites and at sawmills, plywood plants, and other wood processing sites.

SELVA OPTION C-I: LARGE-SCALE CHARCOAL PRODUCTION

The biomass resources available in the Selva are able to support the large-scale production of charcoal for use by Peruvian industries, the feasibility of such an approach should be addressed.

SELVA OPTION D-I: WOOD DISTILLATION

The development of a wood distillation industry in the Selva for the production of alcohols, oils, tars, charcoal, etc. should be assessed. The development of this industry could supply organic substitutes for petroleum-derived materials and fuels.

SELVA OPTION E-I: TRAINING AND EXTENSION

Expansion of on-site training of forestry personnel and development of a forest extension service would help ensure the future productivity of Selva forest.

SELVA OPTION E-II: FORESTRY RESEARCH

Expansion of research on tropical forests and the environmental consequences of their utilization needs to occur.

SELVA OPTION E-III: FORESTRY MANAGEMENT

Identification and development of alternative forest management approaches should take place if greater utilization of forest resource is planned.

SELVA OPTION F-I: COGENERATION

The use of Selva biomass for generation of electricity, steam, and process heat (possibly for district hot water use) should be further studied.

SELVA OPTION G-I: PALM OIL UTILIZATION

Palm oil is a promising avenue to substitute petroleum derived fuel, especially the Brazilian babacu palm Orbignia speciosa that grow in relatively poor soil and in areas too wet for food crop. A palm oil plantation that produces 3,000 metric tons per year is located near the town of Juanjuy south of Tarapotó. This oil could replace some lubricant oil or fuel derived from petroleum. The feasibility of using this resource should be explored.

SELVA OPTION I-I: ETHANOL FROM CASSAVA (YUCCA)

The development of Cassava for both food and fuel (ethanol) purposes should be seriously assessed. Other South American countries (e.g., Brazil) are pursuing this approach which could prove to be a viable option for Peru.

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Appendix A. Explanation of Winter Severity Classification
(Adapted from Papadakis, 1961)

Winter Severity Classification	Mean Annual Minimum	Coldest Month Average Daily Maximum	Other Requirements
• Mild winter wheat belt	-29° to -10°C (-20° to 14°F)	>0°C(32°F)	Mean ann. min. may be higher if cold month av. d. max. is <5°C(41°F)
• Cold winter oats belt	-10° to -25°C (14° to 27.5°F)	5° to 10°C (41° to 50°F)	Mean ann. min. may be higher if cold month av. d. max. is <10°C(50°F)
• Mild winter oats belt	-10° to -25°C (14° to 27.5°F)	>10°C(50°F)	
• Citrus belt	>-2.5°C(27.5°F)	10°-21°C (50°-69.8°F)	Non entirely frostless. Cold month av. d. max. may be higher, if mean ann. temp. is <19°C(66.2°F)
• Cool tropical belt	<15°C(59°F)	<21°C(69.8°F)	Entirely frostless. Cold month av. d. max. may be higher if mean ann. temp. is <19°C(66.2°F)
• Tropical belt	<15°C(59°F)	>21°C(69.8°F)	Entirely frostless. Mean ann. temp. >19°C(66.2°F)
• Equatorial	>15°C(59°F)		

Appendix B. Explanation of Summer Heat Classification
(Adapted from Papadakis, 1961)

Summer Heat Classification	Average of the Average Daily Maximum of n Warmer Months	Frost-Free Season	Other Requirements
• High alpine belt	>10.°C(50.°F) n=4		Av. d. max. of coldest month >17.8°C(0.°F); too cold for low alpine
• Low alpine belt	>10.°C(50.°F) n=4		Av. of the lowest each month of 1 or more months >0°C(32°F)
• Maize belt	>21.°C(69.8°F) n=6	Available 4-1/2 months	Too cold for coffee or cool cotton
• Coffee belt	>25°C(77°F) n=6	Minimum >5 months ¹	Av. d. min. of all months >20.°C(68.°F); summer too cold for warm cotton
• Cool cotton belt	>25°C(77°F) n=6	Minimum >5 months ¹	Summer nights too warm for coffee-too cool for warm cotton
• Warm cotton belt	>25°C(77°F) n=6	Minimum 5 months ¹	Av. d. max. of warmest month >33.5°C(92.3°F)

¹This lapse is reduced to 4-1/2 months when average daily maximum of the warmest month is higher than 33.5°C(92.3°F).

Appendix C. Explanation of Temperature Regimes for Peru
(Adapted from Papadakis, 1961)

Temperature Regime	Winter Severity Classification	Summer Heat Classification
• Hot equatorial	Equatorial belt	Warm cotton belt
• Semi-hot equatorial	Equatorial belt	Cool cotton belt
• Hot tropical	Tropical belt	Warm cotton belt
• Semi-hot tropical	Tropical belt	Cool cotton belt
• Cool tropical	Cool tropical belt	Warm wheat belt or Maize belt or Coffee belt or Cool cotton belt
• Tierra templada	Cool tropical belt or Tropical belt or Equatorial belt	Coffee belt
• Cool tierra templada	Cool tropical belt or Tropical belt or Equatorial belt	Warm wheat belt or Maize belt
• Low tierra fria	Mild winter oats belt or Citrus belt or Citrus-tropical belt	Coffee belt
• Medium tierra fria	Mild winter oats belt or Citrus belt	Maize belt
• Low andine	Mild winter wheat belt or Cold winter oats belt or Mild winter oats belt or Citrus belt	Warm wheat belt
• High andine	Mild winter wheat belt or Cold winter oats belt or Mild winter oats belt or Citrus belt	High alpine belt
• Semi-hot subtropical	Citrus belt	Cool cotton belt

Appendix D. Explanation of Humidity Regime (Adapted from Papadakis, 1961)

Humidity Regime	Annual Humidity Index	Water Surplus	Other Requirements
• Ever Humid	>1.0	>20% evapotranspiration	All months humid
• Humid	>1.0	>20% evapotranspiration	1 or more months not humid
• Dry Mediterranean	Between .22 & .88	>20% evapotranspiration	Winter rainfall greater than summer
• Moist Monsoon	>.88	>20% evapotranspiration	July-August (Jan-Feb southern) have higher humidity indices than April-May (Oct-Nov southern)
• Dry Monsoon	Between .44 & .88	>20% evapotranspiration	July-August (Jan-Feb southern) have higher humidity indices than April-May (Oct-Nov southern)
• Semi-arid Monsoon	<.44		July-August (Jan-Feb southern) have higher humidity indices than April-May (Oct-Nov southern)
• Absolute desert	<.09		Average daily max. for all months >15°C - all months are dry
• Monsoon desert	<.22		All months are dry-humidity index of July-August greater than April-May

Appendix E. Evapotranspiration in Centimeters for Selected Stations in Peru (Source: Dapadakis, 1961)

	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arequipa	8	8	9	10	12	11	10	11	12	11	11	9	122
Cajamarca	7	8	7	7	8	7	9	9	8	8	9	8	95
Cartavio	8	9	8	7	6	5	5	5	5	5	6	7	76
Cerro de Pasco	4	3	4	5	4	5	4	5	4	4	4	5	51
Chachapoyas	6	6	5	6	6	6	6	7	7	7	8	7	77
Chuquibambilla	6	6	6	7	7	8	8	8	8	8	8	7	87
Cusco	8	8	9	9	9	10	10	10	10	10	11	9	113
Huancayo	14	13	11	4	2	1	1	1	4	7	6	8	72
Imata	5	4	4	5	6	6	6	7	7	7	8	6	71
Iquitos	11	10	11	10	9	10	10	12	13	12	12	11	131
Juaja	5	6	5	6	6	6	7	7	7	8	8	6	77
Lambayeque	9	12	12	9	8	6	6	5	6	7	9	9	98
La Molina	11	12	10	10	7	5	4	5	5	7	7	9	92
Lima	9	9	9	8	6	4	4	3	4	6	6	7	75
Lomas de Lachay	5	5	5	3	3	2	1	1	2	2	3	4	36
Mollendo	9	9	8	7	6	5	4	4	4	5	6	7	74
Moquegua	13	14	14	14	14	14	15	15	15	15	15	14	172
Piura	20	20	22	18	15	13	12	14	15	15	16	17	197
Puno	5	6	6	7	7	8	8	8	8	9	8	7	87
San Ramon	22	21	21	15	12	8	8	6	9	16	14	21	173
Tacna	11	13	12	11	8	6	6	7	7	8	10	11	110
Tingo Maria	11	10	11	11	12	13	11	13	13	12	12	11	140
Vitor	14	15	15	16	16	16	16	17	18	17	16	15	191

Appendix F. Annual Residue Production Factors and Energy Value

Commodity	Animal Residue Production Factors	Energy Value of Residue (10 ⁹ Joules)
	$\left[\frac{\text{Ton Residue}}{\text{Ton Production}} \right]$	
Rice	1.5 MT/MT Production	13.4
Oats	2.0 MT/MT Production	13.4
Barley	1.5 MT/MT Production	13.4
Milo	1.0 MT/MT Production	13.4
Maize	1.0 MT/MT Production	13.4
Quina	2.5 MT/MT Production	13.4
Sorghum	1.5 MT/MT Production	13.4
Wheat	1.5 MT/MT Production	13.4
Soybeans	1.5 MT/MT Production	13.4
Plantain	.15 MT/MT Production	13.0
Camote	.15 MT/MT Production	13.0
Potatoes	.15 MT/MT Production	13.0
Cassava	1.0 MT/MT Production	13.0
Cotton	1.0 MT/MT Production	13.4
Peanut	1.0 MT/MT Production	13.4
Sugarcane	.35 MT/MT Production	11.00
Coconut	1.5 MT/MT Production	13.40
Aguafe	1.0 MT/MT Production	13.0
Alpacas	.13 MT/Head	14.6
Poultry	1.1 MT/1000 Head	14.6
Goats	.11 MT/Head	14.6
Horses	1.5 MT/Head	14.6
Llamas	.14 MT/Head	14.6
Pigs	.11 MT/Head	14.6
Sheep	.11 MT/Head	14.6
Cattle	1.7 MT/Head	14.6

AN ASSESSMENT ON MANPOWER
IN PERU

BY

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SUMMARY

One of the primary resources for energy system expansion in Peru will be manpower. At present, the country has an excess supply of labor due to the combined effects of the poor national economic situation and an increasing economically active population. This is reflected in high and growing rates of unemployment and underemployment. Yet most of the current high technology development projects depend heavily upon the services of foreign workers for performance of the sophisticated engineering, management, and skilled manual tasks. This fact supports the general conclusion that the number of highly qualified and experienced Peruvian technical workers needs to be increased, particularly if an active energy expansion program is initiated. Continued dependence upon foreign labor should eventually be abated for social, economic, and philosophical reasons. For social reasons, abatement will increase the number of job opportunities, particularly better paying job opportunities, for Peru's growing labor force. For economic reasons, abatement will decrease the non-trivial amount of money paid to foreign workers rather than Peruvian workers. For philosophical reasons, Peru, with its relatively abundant natural and energy resources, should become more self-sufficient and break the existing pattern of foreign dependency so it can eventually establish the capability and self-confidence required for true self-determination.

Peru has taken major steps under the Education Reform Law of 1972 to improve the availability and practicality of education and training. The planned program is imaginative and aggressive. The primary concern is that the program could collapse or lose momentum due to its large financial requirements, particularly, during the existing national economic difficulties. The activities required to provide the basic education and training of future manpower for energy system expansion have been proposed and are in various stages of development and enactment, but these programs do not fully address the needs for specialized and highly qualified manpower. Continuous reevaluations will be required to assure that successive steps of the education reform produce a pragmatic balance between the social and economic needs of the country. Special efforts must be made by the energy agencies to upgrade the experience factor of its basically trained and educated personnel as this is the primary deficiency of existing energy sector personnel. In-depth studies will be required to identify the special manpower needs and programs will be required for the practical training of the better candidates. Otherwise, future responsibility for executing sophisticated technical tasks will continue to be assigned to foreign personnel and the pattern of dependency, lack of self-confidence and eroding initiative will persist.

NOTE

This Annex was prepared based on information available on September 30, 1978. Data shown in Tables 1 through 4 and Table 8 are thus preliminary and are not consistent with results in Annex 10, which was written subsequently. Although the report contained here uses specific numbers and ratios that have since been modified, the conclusions presented remain valid.

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A. INTRODUCTION

One of the primary resources required for any set of energy options or strategies is manpower. A deficiency of adequately trained and experienced scientific, engineering, managerial, and/or technical (technician, craft or semi-skilled) manpower can adversely affect an otherwise adequately planned energy facility expansion program. Manpower resource deficiencies can be in either or both of two aspects--quantity or quality. If the quantity of required manpower is insufficient or it is unavailable when needed, schedules will slip, interest costs will rise, energy demands will not be met, and planned activities, which will require the energy to be produced, will be delayed. If the quality of the manpower is inadequate, inferior facilities will be created. Such facilities will eventually prove to be unreliable and, thus, unsatisfactory and overly expensive because of their poor performance.

In analyzing the energy related manpower situation of Peru, an attempt was made to consider the quantity, quality and scheduled need for manpower. A paucity of current information on the quantity of existing manpower in Peru has adversely affected the quantitative phase of this analysis.

The quality of manpower can only be inferred by viewing the products presently produced and speculating about the capacity to do better when required. Quality depends not only on the possession of adequate equipment and skills to perform a task, but also upon psychological desire to produce high quality and the financial support to pay the added price that improved quality may require.

Unavailable manpower can never perform the desired function. In such a case, the projects must either be deferred until the manpower becomes available or the needed manpower must be obtained from alternative (usually outside) sources. Although the latter solution is possible, financial considerations (generally higher costs and adverse affects on national balance of payments) make this solution undesirable, particularly for long-term programs.

Adequate training to efficiently and expertly direct energy expansion projects presupposes that the involved middle-level managers have had meaningful past experience on which to base their expanded role of authority and accountability. Likewise, senior personnel are expected to have had meaningful past experience at the middle management level as a basis for their increased authority and responsibility.

The manpower planning and development tasks in Peru will be formidable as the country attempts to enact measures necessary to improve its social and economic conditions. Even if one assumes that the country's education and training facilities perform their tasks in the most exemplary manner, the initial phases of the future expansion and modernization of energy facilities will be hectic, demanding, and, in all probability, beyond the capability of the country to perform without outside assistance. The added sophistication of modern energy technology, accelerated rates of enactment, and incorporation of totally new options will promote increasing need for outside assistance, both technological and financial. Manpower development is only one of the factors for which accurate and realistic preplanning will produce large returns as the energy program expands to the year 2000 and beyond.

B. PROJECTED MANPOWER NEEDS OF THE ENERGY SYSTEM EXPANSION STRATEGIES

Resource requirements of the various energy system expansion options were prepared via a computer program which contains, among other information, the manpower resource estimates for the design, construction, startup, operation, and maintenance of a large number of common and developmental energy supply systems. Computer produced estimates of total and foreign manpower requirements for the mix of energy supply options identified for the reference case strategy are shown in Tables 1-4. These manpower estimates were used as the basic manpower demand for the analysis of manpower resource deficiencies in Section D below.

C. EXISTING MANPOWER RESOURCES OF PERU

Peru's Education Reform Law of 1972 was designed to correct shortcomings perceived in the Peruvian economic sector by the reform authors. Among the perceived shortcomings were:

- A shortage of technical manpower, especially middle level technical manpower, relative to the supply of academic graduates in traditional fields.
- An overemphasis on academic training with a concomitant underemphasis of practical knowledge. This condition was seen to exist at all levels but was particularly sensed at the higher levels of education, grade levels 10, 11, 12 and the university levels.
- A maldistribution of qualified manpower caused by failure to match training provided with the areas in which it was needed (e.g., teaching rurally applicable subjects in urban areas and vice versa).

These determinations and the resulting corrective education reform programs were designed in the early 1970s and were based on data obtained for the 1972 census, the period just prior to the oil crisis. Economic conditions in Peru, at that time, although not totally satisfactory, were more stable, predictable, and balanced than they have since been.

The 1972 census was the latest general census taken in Peru. Thus, it contains the latest nationwide manpower resource information available. Tables 5-7 list some of the 1972 technical manpower resources of Peru which are pertinent to an energy expansion program. Later manpower data that exists were either regional in coverage, insufficiently disaggregated and/or were based on sample survey data only. No attempt was made at extrapolation of regional or sample survey data since the correlations for such data are unknown. Thus, determination of whether or not the same shortcoming perceived by the authors of the educational reform persist in the energy sector cannot be documented with any real degree of certainty. Obviously, this data deficiency will need to be rectified before precise mismatch between energy-related education and employment can be identified.

TABLE 1

Manpower Requirements (Man Years)
for Design, Construction, and Startup*-Reference Case (High Oil)

Category	Annual Requirements			
	1977 Calculated	2000	1977-2000 Average	Peak (Year)
Chemical Engineers	7	23	15	23 (1997)
Civil Engineers	209	477	314	476 (2000)
Electrical Engineers	59	225	158	225 (2000)
Mechanical Engineers	89	227	157	227 (2000)
Mining Engineers	0	2	1	1 (2000)
Nuclear Engineers	0	0	0	0
Geological Engineers	66	105	77	105 (2000)
Petroleum Engineers	52	77	60	77 (2000)
Other Engineers	4	15	9	15 (2000)
Engineers Total	481	1,151	791	1,151 (2000)
Designers & Draftsmen	180	492	332	492 (2000)
Supervisors & Managers	205	422	272	422 (2000)
Nonmanual, Tech. Total	866	2,065	1,395	2,065 (2000)
Nonmanual, nontech.	163	384	270	384 (2000)
Nonmanual Total	1,029	2,449	1,665	2,449 (2000)
Pipefitters	427	866	626	1,094 (1991)
Pipefitters/welders	491	836	622	966 (1991)
Electricians	376	1,172	743	1,172 (2000)
Boilermakers	69	159	156	531 (1990)
Boilermakers/welders	279	732	437	732 (2000)
Ironworkers	304	1,001	619	1,001 (2000)
Carpenters	566	1,657	1,002	1,657 (2000)
Equipment Operators	1,634	4,336	2,565	4,336 (2000)
Lineman	1,411	2,489	1,848	2,489 (2000)
Teamsters & Laborers	2,426	6,686	3,992	6,686 (2000)
Other	2,205	3,154	2,250	3,154 (2000)
Manual Total	10,188	23,088	14,860	23,088 (2000)
Manual Total	11,217	25,537	16,525	25,537 (2000)

*Includes requirements for energy supply and transportation facilities.

TABLE 2

Manpower Requirements (Man Years)
for Operation and Maintenance*-Reference Case (High Oil)

Category	Annual Requirements			
	1977 Calculated	2000	1977-2000 Average	Peak (Year)
Chemical Engineers	28	68	43	68 (2000)
Civil Engineers	18	50	31	50 (2000)
Electrical Engineers	30	75	49	75 (2000)
Mechanical Engineers	30	77	50	77 (2000)
Mining Engineers	0	9	2	9 (2000)
Nuclear Engineers	0	0	0	0
Geological Engineers	4	8	6	8 (2000)
Petroleum Engineers	12	25	19	25 (2000)
Other Engineers	13	34	20	34 (2000)
Engineers Total	135	346	220	346 (2000)
Designers & Draftsmen	38	103	66	103 (2000)
Supervisors & Managers	490	1,577	910	1,577 (2000)
Other Technical	294	963	550	963 (2000)
Nonmanual, Tech. Total	957	2,989	1,746	2,989 (2000)
Nonmanual, nontech.	932	3,129	1,759	3,129 (2000)
Nonmanual Total	1,889	6,118	3,505	6,118 (2000)
Pipefitters	219	589	354	589 (2000)
Welders	169	393	276	393 (2000)
Electricians	441	1,720	932	1,720 (2000)
Boilermakers	41	99	61	99 (2000)
Mechanics	1,085	3,696	1,985	3,696 (2000)
Machinists	266	701	424	701 (2000)
Ironworkers	23	92	53	92 (2000)
Carpenters	42	127	76	127 (2000)
Equipment Operators	243	3,453	1,248	3,453 (2000)
Other Operators	1,347	4,420	2,573	4,420 (2000)
Meter Readers	572	2,121	1,206	2,121 (2000)
Teamsters & Laborers	2,597	7,991	4,627	7,991 (2000)
Lineman	176	880	454	880 (2000)
Other	851	2,997	1,614	2,997 (2000)
Manual Total	8,072	29,279	15,883	29,279 (2000)
Manpower Total	9,961	35,397	19,388	35,397 (2000)

*Includes requirements for energy supply and transportation facilities.

TABLE 3

Foreign Component* of Manpower Requirements (Man Years)
for Design, Construction, and Startup**-Reference Case (High Oil)

Category	Annual Requirements			
	1977 Calculated	2000	1977-2000 Average	Peak (Year)
Chemical Engineers	2	17	11	17 (1997)
Civil Engineers	144	324	214	324 (2000)
Electrical Engineers	38	146	101	146 (2000)
Mechanical Engineers	66	164	114	164 (2000)
Mining Engineers	0	1	1	1 (2000)
Nuclear Engineers	0	0	0	0
Geological Engineers	64	101	74	101 (2000)
Petroleum Engineers	52	77	60	77 (2000)
Other Engineers	2	11	7	11 (2000)
Engineers Total	368	841	582	841 (2000)
Designers & Draftsmen	141	372	249	372 (2000)
Supervisors & Managers	197	415	265	415 (2000)
Nonmanual, Tech. Total	706	1,628	1,096	1,628 (2000)
Nonmanual, Nontech.	143	324	226	324 (2000)
Nonmanual Total	849	1,952	1,322	1,952 (2000)
Pipefitters	358	714	518	910 (1991)
Pipefitters/welders	143	238	178	278 (1991)
Electricians	165	496	314	496 (2000)
Boilermakers	31	72	72	240 (1990)
Boilermakers/welders	120	325	190	325 (2000)
Ironworkers	137	453	282	453 (2000)
Carpenters	164	492	299	492 (2000)
Equipment Operators	101	284	172	284 (2000)
Lineman	6	123	88	163 (1981)
Teamsters & Laborers	0	0	0	0
Other	871	1,207	830	1,207 (2000)
Manual Total	2,096	4,404	2,943	4,407 (2000)
Manpower Total	2,945	6,356	4,265	6,360 (2000)

*Foreign workers required if existing pattern of manning technical projects is continued.

**Includes requirements for energy supply and transportation facilities.

TABLE 4

Foreign Component* of Manpower Requirements (Man Years)
for Operation and Maintenance**-Reference Case (High Oil)

Category	Annual Requirements			
	1977 Calculated	2000	1977-2000 Average	Peak (Year)
Chemical Engineers	18	43	28	43 (2000)
Civil Engineers	8	18	12	18 (2000)
Electrical Engineers	14	25	19	25 (2000)
Mechanical Engineers	16	34	24	24 (2000)
Mining Engineers	0	4	1	4 (2000)
Nuclear Engineers	0	0	0	0
Geological Engineers	4	6	6	6 (2000)
Petroleum Engineers	11	23	17	23 (2000)
Other Engineers	8	20	12	20 (2000)
Engineers Total	79	173	119	173 (2000)
Designers & Draftsmen	25	56	40	56 (2000)
Supervisors & Managers	236	645	407	645 (2000)
Other Technical	161	444	277	444 (2000)
Nonmanual, Tech. Total	501	1,318	843	1,318 (2000)
Nonmanual, Nontech.	0	0	0	0 (2000)
Nonmanual Total	501	1,318	843	1,318 (2000)
Pipefitters	20	48	30	48 (2000)
Welders	69	142	106	142 (2000)
Electricians	80	188	127	188 (2000)
Boilermakers	6	15	9	15 (2000)
Mechanics	157	412	264	412 (2000)
Machinists	30	66	47	66 (2000)
Ironworkers	1	2	1	2 (2000)
Carpenters	5	11	7	11 (2000)
Equipment Operators	11	177	59	177 (2000)
Other Operators	194	461	307	461 (2000)
Meter Readers	4	7	4	7 (2000)
Teamsters & Laborers	259	657	446	657 (2000)
Lineman	0	9	3	9 (2000)
Other	290	674	462	674 (2000)
Manual Total	1,126	2,869	1,872	2,869 (2000)
Manpower Total	1,627	4,187	2,715	4,187 (2000)

*Foreign workers required if existing pattern of manning technical projects is continued.

**Includes requirements for energy supply and transportation facilities.

TABLE 5

EXCERPTS FROM 1972 CENSUS TABLE OF ECONOMICALLY
ACTIVE POPULATION BY LEVEL OF EDUCATION

Level of Education	Economically Active Population 6 years or older
1. All Levels (total)	3,871,613
2. Technical Secondary School	124,731
1 year	15,514
2 year	20,549
3 year	23,576
4 year	11,528
5 year	48,335
6 year	4,478
Year not specified	751
3. University	177,145
Geology	507
Physics	239
Chemistry	866
Statistics	223
Science (not classified)	376
Mathematics	504
Mathematical Physics	177
Economics	4,555
Planning	53
Engineering Administration	33
Civil Engineering	4,077
Electrical Engineering	644
Geophysical Engineering	452
Mechanical Engineering	2,285
Petroleum Engineering	164
Systems Engineering	72

Reference: Censos Nacionales VII de Poblacion II de Vivienda-Cuadro No. 25,
Oficina Nacional de Estadística y Censos, Lima, Agosto 1974.

TABLE 6

EXCERPTS FROM 1972 CENSUS TABLE OF EMPLOYED
POPULATION BY PRIMARY OCCUPATIONAL GROUPING

Occupational Code	Occupational Group	Number Employed
001	Chemist	456
002	Physicist	15
003	Physical Chemist	627
011	Architect	918
013	Civil Engineer	3,366
015	Electrical Engineer	632
016	Mechanical Engineer	1,335
017	Chemical Engineer	1,115
018	Metallurgical Engineer	100
019	Mining Engineer	755
020	Industrial Engineer	550
024	Surveyor	2,532
025	Draftsman	3,143
026	Civil Engineering Technician	1,167
027	Electrical Technician	3,849
028	Mechanical Technician	2,741
029	Chemical Industry Technician	206
030	Metallurgical Technician	161
031	Mining Technician	162
004	Physical Chemistry Technician	3,058
096	Planner	47
701	Foremen	5,722
711	Miner	22,616
712	Mine Worker	2,794
721	Metal Furnace Worker	1,365
819	Not Specified Wood Worker	1,326
831	Blacksmith	4,382
832	Mechanics (excluding automotive engine, and repair mechanics)	596

TABLE 6 (cont'd)
EXCERPTS FROM 1972 CENSUS TABLE OF EMPLOYED
POPULATION BY PRIMARY OCCUPATIONAL GROUPING

Occupational Code	Occupational Group	Number Employed
834	Machinist	2,052
854	Electronic Technician	4,053
855	Electrician	15,518
857	Lineman	417
859	Unspecified Electrician	332
871	Plumber	6,590
872	Welders	12,791
874 & 875	Metal Workers	390
952	Reinforced Concrete Worker	1,622
954	Carpenter	44,746
956	Insulation Material Installer	52
959	Not Specified Construction Worker	20,127

Reference: Censos Nacionales VII de Poblacion II de Vivienda--Cuadro No. 29,
Oficina Nacional de Estadística y Censos, Lima, Agosto 1974.

TABLE 7

EXCERPTS FROM 1972 CENSUS TABLE OF EMPLOYED POPULATION
BY ACQUIRED PROFESSION OR FUNCTION

Occupational Code	Profession	Total Employed Pop. 15 yrs. or Older	Function		
			Prof., Tech. & Similar Level	Director or Manager	Other Workers & Assoc. Employees
	Total	3,572,326	278,534	15,685	3,278,107
013	Hydraulic Engineers	4,111	3,633	209	269
015	Electrical Engineers	578	481	45	52
019	Petroleum Engineers	971	737	168	66
024	Surveyor	1,757	1,584	10	163
027	Electrical Technician	2,431	1,913	27	491
029	Engineering Technician	170	138	11	21
031	Mining Technician	173	85	7	81
040	Electronic Technician	2,382	1,577	28	777
213	Oil Well Drill Operator	247	1	1	245
831	Blacksmith	4,363	9	--	4,354
840	Unspecified Mechanics (Excluding Air, Auto, & Marine Mechanics)	14,896	360	53	14,483
851	Electrical Installer	1,300	13	4	1,283
852	Electronic Installer	199	1	--	198
856	Electrician	435	5	--	430
871	Plumber	6,237	17	1	6,219
872	Welder	10,947	61	8	10,878
951	Construction Laborer	85,898	362	14	85,522
954	Carpenter	51,042	408	27	50,607
973	Crane Operator	438	14	1	423
974	Bulldozer Operator	1,850	5	--	1,845
979	Materials Truck Driver	199	--	1	198

Reference: Censos Nacionales VII de Poblacion II de Vivienda--Cuadro 38, Oficina Nacional de Estadística y Censos,
Lima, Agosto 1974.

TABLE 8

Comparison of Manpower Requirement, Supply and Training Capability

Labor Category	Annual Manpower Requirements (Man Years)		Avg. Yearly Additions Req'd from 1977-2000 (man years)	Number in Work Force Noted 1972 Census	Number of Graduates in 1975
	1977 (Calculated)	2000			
<u>Nonmanual, Technical</u>					
Chemical Engineers	30	91	2.7	1,115	259
Civil Engineers	227	527	13.0	3,366	248
Electrical Engineers	89	300	9.2	578-632	129 ^d
Mechanical Engineers	119	304	8.0	1,335	310 ^e
Mining Engineers	0	11	0.5	755	32
Geological Engineers	70	113	1.9	959 ^b	36
Petroleum Engineers	64	102	1.6	971	0
Other Engineers	17	49	1.4		
Designers & Draftsmen	218	595	16.4	3,143 ^c	
Supervisors & Mgrs.	695	1,999	56.7		
Other Technical	294	963	29.1		
<u>Nonmanual, Nontechnical</u>	1,095	3,513	105.1		
<u>Manual</u>					
Pipefitters	646	1,455	35.2		
Welders ^a	939	1,961	44.4	12,791	
Boilermakers	110	258	6.4		
Electricians	817	2,892	90.2	15,518	
Ironworkers	327	1,093	33.3		
Carpenters	608	1,784	51.1	44,746	
Equipment Operators	1,877	7,789	257.0		
Other Operators	1,347	4,420	133.6		
Linemen	1,587	3,369	77.5	417	
Mechanics	1,085	3,696	113.5	596	1,164
Machinists	266	701	18.9	2,052	
Meter Readers	572	2,121	67.3		
Teamsters & Laborers	5,023	14,679	419.8		
(construction)	(2,426)	(6,686)		85,898	
(operation)	(2,597)	(7,993)			
Other Manual	3,056	6,151	134.6		
Total	21,178	60,936	1728.4		

Notes:

- Combined total of welders, pipefitter/welders and boilermaker/welders.
- Total of geologists and geophysical engineers.
- Draftsmen only.
- Total of electrical, electronic, and industrial and electric control graduates plus one half of electromechanical graduates.
- Total of mechanical, industrial, and one half of electromechanical graduates.

The task of determining existing and future interactions between national employment and education has recently been assigned to an interministerial commission. Definition and development of computer models to project this interaction are in progress but to date no results usable for the energy supply system manpower analysis have been produced. Although the 1972 manpower data are outdated, the 1972 census data is the only data base usable for the energy related manpower analysis.

D. COMPARISON OF MANPOWER NEEDS, SUPPLY AND INDIGENOUS TRAINING CAPABILITY

Table 8 contains the comparative data of the manpower development information collected or developed during the Peru/U.S. Cooperative Energy Assessment. Columns 1 and 2 show the current (calculated) and projected total manpower needs for the reference case (high oil) strategy of energy development in Peru. Column 3 shows the average number of workers that must be added per year to expand the 1977 work force to meet the requirements of the year 2000 (peak year) work force. The numbers were derived by dividing the difference between columns 1 and 2 by 23, the number of years from 1977 to 2000. Column 4 shows the number of workers by labor types for which specific 1972 census data was found. As noted previously, the 1972 census data were used since that is the latest census which is national in coverage, based on a total survey (as opposed to sample surveys) and sufficiently disaggregated to allow some degree of meaningful comparison. Column 5 is a list of the 1975 technical graduates which were noted as required and for which specific numbers were found (See Section E). Blank spaces were left in columns 4 and 5 wherever the data was unavailable or insufficiently defined to assure that proper comparisons could be made.

Since the existing energy supply system is being operated and expanded whenever funds can be allocated to such expansion, it must be assumed that the current manpower requirements are being met. Comparison of columns 1 and 4, however, provide an insight into the condition which might exist if current financial constraints were removed and the manpower requirements for an active, aggressive program of energy system expansion already existed.

The resources of most non-manual, technical personnel--specially the chemical, civil, mechanical, mining, and geological engineers and the draftsmen--appear to be already adequate in number and trained in large enough quantity to allow the postulated increase in activity without encountering unusual manpower shortage problems. The manpower requirements as a percentage of the manpower resources for these specific labor types range from 0 to 8.9% while the additional yearly requirements from 1977-2000 as a percentage of 1975 graduates range from 1.0 to 5.3%.

The ratio of petroleum engineers required in 1977 to petroleum engineers identified in the 1972 census is 6.6%. Although the ratio is not very high considering that the manpower requirements of the analysis also include the supply and transportation requirements, the fact that no petroleum engineers were graduated in 1975 is somewhat disturbing. It should be noted, however, that one of the universities, Universidad Nacional de Ingeniera, offers a major in petroleum engineering and grants bachelor of science degrees in petroleum engineering.

The most disturbing non-manual, technical labor situation is that which exists in electrical engineering. In this case, the ratio of 1977 requirements to 1972 work force appears to be relatively high (14.1%) considering the broad spectrum of other activities for which such individuals would be required. The fact that the future yearly additions for the energy program are estimated to be 7% of the electrical (and electronic) engineers produced is misleading. Only 2 of the 129 electrical, electromechanical, electronic, and industrial and electronic control engineers were actually graduate electrical engineers and the primary specialty needed for the labor category of the energy program listed as electrical engineers is electrical engineers. This being the case, the 9.2 additional engineers needed each year is 460% of those produced in 1975. Thus, the present requirement for electrical engineers represents a relatively large percentage of the existing field and the average yearly requirement for additional workers in the field is many times the number currently being trained. This situation if uncorrected could produce serious adverse impacts on the future energy expansion program.

For the few manual laborer categories where existing work force data and training capacity data were found, the manpower picture produced is also mixed. The specific labor categories for which data was found and which appear to be adequate are welders, electricians, carpenters and construction laborers. In these categories, the energy system requirements are reasonably modest when compared to the work force. The present requirement for mechanics, however, is almost two times (182%) the 1972 work force. These workers would probably be in very short supply if the present economic situation of the country were better. The future situation for mechanics (in this listing the term mechanics excludes automotive, airplane, marine and engine mechanics) would probably be troublesome since the yearly required additions are approximately 10% of the number trained. This would probably require the frequent use of mechanical technicians and/or inadequately trained personnel if an active, aggressive energy expansion program were attempted concurrently with an expanding economy.

The ratio of required machinists to those in the work force (13.0%) is also quite large considering the broad spectrum of activities that require such personnel. The number of linesmen required in 1977 is almost four times the number identified in the 1972 work force. One can only speculate what the present employment situation is but this is a category to which the electric system and communication system managements must pay particular attention. The requirements in the energy sector alone appear to be sufficient to justify the establishment of several training classes per year. An equivalent number of classes would probably be required for communication linesmen also.

For the reference case (high oil), the projected construction manpower requirement of the year 2000 is 25,537 and the projected operation and maintenance manpower requirement is 35,399 (See Tables 1 and 2). If the current method of operation (i.e., substantial dependence on expatriate workers for high skill or technically sophisticated tasks) is used in the year 2000, the requirement for expatriate workers for construction may be as high as 25%; and the requirement for expatriate workers for operation and maintenance may be as high as 12%. Under such conditions, the projected labor force of 60,936 may include as many as 10,547 foreign workers. The cost of these foreign workers is estimated to be \$167 million per year (See manpower cost estimates in annex regarding cost, equipment and manpower requirements). The net result would be that by the year 2000 Peru could, by providing sufficient numbers of high quality indigenous manpower, not only save a substantial

part of the estimated \$167 million per year but could also provide a substantial number of the 10,547 man years of job opportunity to its own labor force. It is doubtful that the costs to the country to support the needed quantity and quality of training programs would be more than a small fraction of the added yearly cost of using foreign workers. Thus, both economic and social reasons exist for Peru to seriously plan and develop a strong capability for producing the high quality energy-related manpower it will increasingly require.

Several of the categories in the Table 6 column "Number in Work Force Noted in 1972" (e.g., pipefitters, boilermakers, ironworkers) are the precise categories for which many of the expatriate manual workers are presently employed. Other skilled manual labor jobs as well as non-manual labor jobs (e.g., designers, supervisors, managers) are frequently filled by expatriates. The commonality of the expatriate assignments is the extra degree of skill and/or experience such tasks require. A survey of Peruvian energy related expatriate worker assignments (both those being performed in Peru and those being performed outside of Peru) would provide a fairly good indication of the types of manpower and, hence, manpower development activities that are needed to make Peru more self-sufficient. Such a survey should prove to be a worthwhile and highly informative exercise both for the energy manpower planners and the education system planners. Those job categories to which significant numbers of foreign workers are assigned should be added to the list of job descriptors of the census forms so that future trends of Peruvian employment for these categories may be followed. Special corrective actions may be required if continued dependence upon expatriate workers is to be abated.

E. MANPOWER EDUCATION AND TRAINING RESOURCES OF PERU

The only types of manpower considered in this assessment are those required to enact programs of energy facility design, construction, startup, operation, and maintenance. Although unskilled labor and non-technical personnel (e.g., clerical and other office personnel) will be required, such personnel require relatively little training and should be readily available in the labor market when required. Therefore, such labor types have been ignored in this analysis. Other labor types (e.g., scientists, engineers, technical managers, technicians, craftsmen, and semi-skilled laborers), however, will not be as readily available. The assured availability of such labor types is crucial to enactment of any proposed energy project or program. The commonality of these latter labor types is the fact that each requires an extra degree of education (academic instruction) and/or practical experience (vocational practice) to perform its task.

The basic training of personnel is and will continue to be the task of the formal academic institutions and vocational training facilities of the country itself. For proper analysis of the manpower production capabilities of Peru, therefore, it is important to examine the existing and proposed educational system to determine its capability to produce trained manpower, and investigate the types and quality of the manpower which it produces.

The formal education system of Peru is well established and heavily supported. In 1978 approximately 14.3% of the national budget was allocated to the Ministry of Education¹. The major task of the present educational system is to improve its efficiency to free additional funds for further development since increased allocation is unlikely under present economic conditions.

Peru has 33 universities, the oldest (San Marcos) was founded in 1551 and the newest (Santiago Antunez de Mayolo) was created in 1977^{2,3}. All universities operate under the guidance of the Consejo Nacional de la Universidad Peruana (CONUP). The universities offer a combined total of 422 academic programs and have a combined total of 308 academic departments². Twenty-three (23) of the universities are public facilities while the remaining 10 are private². All support for the public and much of the funds of the private universities are obtained from the central government budget. A university education is theoretically available to all but is predicated on ability as established by entrance examination. In actuality, however, the number of applicants for admission exceeds by about a factor of three the number of students that actually enter the university. Due to the larger population of applying students in recent years, the number of applicants turned away has risen dramatically while the number of students entering the universities has increased only slightly. In 1976, the number of entrants to the university was 41,338⁴. These entrants were only 24.5% of the 168,637 persons who applied for admission⁴. In 1975, the 180,857 matriculating students was made up in part of 40,840 entrants from a field of 145,253 applicants⁴. The number of graduates produced that year, however, was only 8,525⁴. Thus it appears that only about 21% of the enrolled students in a year class eventually complete the schooling they set out to achieve.

The universities have traditionally supplied independent commentary, criticism, and research on the processes occurring in society. Complete independence, however, is not realistic in view of the heavy support for universities derived from the central government budget. The question of how to provide this financial support without relinquishing academic independence is an ever present dilemma for the Peruvian Universities.

The academic curriculums for scientists and engineers which are of particular interest to the energy expansion program, the number of universities offering each curriculum, and the number of graduates in 1975 is shown in Table 9.

The number of students graduated per year compared to the number of university departments offering the technical curriculum is widely variable. For example, on average, the six universities offering architecture each produced about 40 graduates in 1975 and the eight universities offering civil engineering each produced about 31 graduates in 1975. At the other extreme, however, the lone university offering geophysics, hydrology, engineering science, engineering administration, geophysical engineering, fluid mechanical engineering, petroleum engineering, and planning produced no graduates in 1975. Worse yet is the performance in systems engineering where neither of the two university curricula produced a graduate. The reasons for the surprisingly low graduate production rates by the technical departments of the universities is unknown to this analyst but is most disturbing at first glance.

The subuniversity levels of public education are directly under the control of the Ministry of Education. Private subuniversity level educational facilities exist. These facilities are subject to the direction of the Ministry of Education for their curriculum design and presentation materials.

TABLE 9

SUMMARY OF UNIVERSITY TRAINING OF SPECIAL INTEREST FOR
THE ENERGY EXPANSION PROGRAM

Academic Curriculum	No. of Graduates ¹ - 1975	No. of Professional Certifications ² - 1975	No. of Universities Offering the Curr. - 1976	Advanced Degree Programs (1975 Degrees Conferred)
1. Architecture	236	91	6	
2. Biology (for environmental analysis needs)	124	109	11	M.S. (0), Ph.D. (0)
3. Statistics	6	14	5	M.S. (0)
4. Structures				M.S. (0)
5. Physics	14	15	5	M.S. (0), Ph.D. (0)
6. Mathematical Physics	9	1	1	
7. Geophysics	0	0	1	
8. Hydraulics	0	0	1	
9. Applied Hydro Mechanics	M.S. only	M.S. only	1	M.S. (0)
10. Engineering Science	0	0	1	
11. Engineering - Administration	0	1	1	
12. " - Civil	248	154	8	M.S. (0)
13. " - Indust. & Elect. Control	3	0	1	
14. " - Electrical	2	2	4	M.S. (0)
15. " - Electronics	56	5	2	M.S. (0)
16. " - Forest	17	15	3	
17. " - Geophysical	0	0	1	
18. " - Geological	36	26	4	
19. " - Industrial	156	30	10	M.S. (0)
20. " - Mechanical	66	4	3	
21. " - Electromechanical	136	2	3	
22. " - Fluid Mechanical	0	2	1	
23. " - Metalurgical	13	2	8	
24. " - Mining	32	16	9	
25. " - Petroleum	0	1	1	M.S. (0)
26. " - Chemical	259	153	10	M.S. (0)
27. " - Systems	0	0	2	M.S. (0)
28. Planning	0	0	1	
29. Chemistry	19	28	8	

¹Completed Academic Requirements Only²Completed Academic, Civil Service, Thesis and Certification ExaminationReferences: Grados y Titulos que Otorga la Universidad Peruana,
CONUP, Lima, 1976.Graduados y Titulados en la Universidad Peruana
Anos: 1970-1975, Boletin Estadistico No. 8, CONUP,
Lima, July 1977.

Following the revolution in 1968, the government of Peru reassessed and reorganized the subuniversity level educational system. The vehicle of this reorganization was the Education Reform Law of 1972. The primary purpose of the reform was to complement the goals of the revolution. Its primary goal was to reconcile the humanistic and economic needs of society, that is, to insure that the individuals receiving the education become beneficiaries of the fruits of the production process as well as factors of that production.

The early efforts of the education reform were mostly directed toward reducing illiteracy by increasing the availability of education. Thus, early efforts were directed at the primary or basic education levels. Since this level of education serves only as a base for the types of technical workers being addressed in this analysis, no discussion of these reforms will be attempted here.

The professional level technical personnel will be supplied by the universities. Most of the middle level technical workers and skilled manual laborers, however, will be obtained from the subuniversity education and training facilities. Under the education reform law the subuniversity educational system was changed from the classical system of primary, elementary, and secondary schools to a system consisting of nine years of basic education followed by three years of combined vocational and academic training in a special type of school called "Escuelas Superiores de Educacion Profesional" (ESEP). At the present time about 20% of the 10th, 11th, and 12th year level students receive training at this type of facility. Present plans call for total conversion to this system by the year 1980.

The primary purpose of the ESEPs is to provide the graduates with practical, job-related skills that enhance their opportunity for job placement and ability to accomplish productive work. The courses presently offered and proposed are diverse (e.g., teaching, technical trades, commercial skills). This aspect of the reform was enacted in 1975. The first graduates have just completed the required three years of training. Table 10 is a list of the presently established training courses which are pertinent to the manpower needs of an energy expansion program. The number of graduates shown is the anticipated number of graduates to be produced in this first cycle and were obtained from unpublished data of the Ministry of Education. Other pertinent courses are listed which have already been established, but the first cycle of graduates will not be produced for one or two years.

Sixteen (16) ESEPs have been created to date using internally generated funds as well as foreign assistance funds (e.g., Canada, West Germany, British Council, German Evangelic Church, IBRD). Sixteen (16) additional ESEPs are in the final stage of planning but their establishment will depend upon approval of a second IBRD loan. With proper input to the Ministry of Education during the curriculum development stage from the agencies responsible for energy expansion, these schools could become an excellent source of the basic training of middle level manpower for the future energy expansion program.

A second type of educational facility has been devised and is being actively promoted under the education reform law. These facilities are called Centros de Calificacion Profesional Extraordinaria (CECAPEs). The purpose of the CECAPEs are:

TABLE 10

ESEP TRAINING COURSES APPLICABLE TO MANPOWER
REQUIREMENTS OF AN ENERGY EXPANSION PROGRAM

Courses	No. of Graduates Expected in 1978
Construction & Topography	389
Electricity & Electronics	663
Minerals & Metallurgy	493
Mechanics	1,164
Petroleum	259
Computers	*
Chemical Control & Instrumentation	*
Laboratory Technology	*

*First cycle of three-year training not yet completed.

Source: Unpublished data of the Ministry of Education.

- to train vocational apprentices for entering specific occupations,
- to develop and improve in-service training for workers,
- to train workers for independent occupational activities,
- to train the unemployed and the underemployed to enable them to qualify for specific occupations in fields where job openings exist, and
- to provide retraining and rehabilitation training for workers in changing labor fields and areas.

Both public and private CECAPes presently exist and are designated as CENACAPes or CENECAPEs depending on whether they are public or private facilities, respectively. In 1978 there were 240 CENACAPes (public), with a combined total of 1,876 teachers and 76,900 students of which 66,300 students were enrolled on a formal basis and 10,600 were enrolled on a non-formal basis⁵. Courses being offered in the CECAPes are many and varied. Courses are almost exclusively vocational by design, and include such subjects as beautician training, auto mechanics, drafting, computer programming, welding, machine shop practices, etc. Although the number of CENECAPEs (private), their courses, number of teachers, and number of students is less; a significant amount of educational opportunities are also available in these facilities. Precise numbers for these facilities, however, were not shown in the data received.

The CECAPes should prove to be an excellent vehicle for the basic training of skilled and semi-skilled manual laborers. The agencies responsible for implementation of the energy expansion program should, however, offer assistance and actively follow course planning and development to insure that sufficient numbers of individuals are produced to satisfy future energy development manpower needs.

Another training resource of Peru is the Servicio Nacional de Apprendizaje y Trabajo Industrial (SENATI). This training resource is completely separated from the education and training resources of the Ministry of Education. Support for SENATI is obtained through the assessment of all companies in Peru which employ more than 15 workers. An assessment of 1-1/2% of the salaries paid to the workers is levied on the companies to support the activity. Training courses are strictly job related. Training is provided to all levels of employees from the unskilled workers to the middle management levels. Although the primary focus is apprenticeship training, on-the-job upgrading training for skill improvement or worker rehabilitation is also included in the program. Technical assistance for training design, development and execution are often obtained through bilateral agreements with foreign governments (e.g., France, West Germany, Netherlands).

It appears that most of the indigenous training elements needed for future energy-related middle level and skilled manpower requirements are in place and being expanded. The primary concern is that the educational reform plans may be too aggressive and could, therefore, fail to materialize due to the heavy financial requirements of the reform program and the poor financial condition of the country. At present, however, the situation seems to be that more basically trained individuals are being produced than the present low level of economic activity can support.

The quality of training received and the capability of the trained individuals appears to be widely variable from very good to very poor. Most of the programs appear to derive from the newness of the programs, the inability of the teachers to adapt to the demands of the new (vocational rather than academic) style of education, and the absence or shortage of physical facilities, equipment, text, etc., due to the shortage of funds. These problems, hopefully, will be resolved with time and an improvement of economic conditions.

F. OTHER FACTORS TO BE CONSIDERED

The following are other factors which must be considered with regard to energy manpower development.

1. Unemployment and Underemployment--Peru is experiencing a steady growth in its labor force. This is primarily the result of the increases in population over the past decades. The labor force, which in 1960 was estimated to be 3,127,000, was estimated to be 4,473,000 in 1975⁶. This is equivalent to a 2.4% per year increase in employment requirements. Because of the trend toward urbanization, an even larger rate of growth of employment demand exists in the non-agricultural labor market. It is estimated that by the year 2000 the number of persons in the labor force will increase to 9,740,000⁶. Thus, an approximately 3.2% per-year rate of growth of employment demand is anticipated to occur from the present to the year 2000. Since the bulk of the new workers involved have already been born the employment demands to the year 2000 have already been fixed.

At present, however, the primary factor impacting the labor market (i.e., labor demand and supply) of Peru is the economic situation of the country. The severely depressed economic situation has caused a shortage of federal funds to finance all but the most necessary projects. Thus, even projects having high government priority have been curtailed and are closely scrutinized to eliminate waste and extravagance. If the depressed financial situation continues, many of the planned programs and approved projects will experience funding difficulties which could eventually lead to their slow down or stoppage. The financial squeeze on the private sector is equally severe and has caused a pronounced curtailment of its normal activities also. Both situations are producing additional increases in unemployment and underemployment. Unemployment in Peru, which in 1971 was listed as being about 4%, rose to slightly above 5% in 1976⁷. The primary reason that unemployment is not greatly higher is the stabilizing effect of the Labor Stabilization Law which prohibits the laying off or firing without extreme justification of any employee with over three years of service. Consequently, increases in unemployment

primarily reflect the growing number of unemployed persons who have just recently entered the employment market. The measure of the effect upon employees with three or more years of service is the underemployment rate. This rate for non-agricultural workers of the economically active population has increased from 30% in 1971 to 46.2% in 1976⁷. Although later figures for Peru have not been identified, it is highly probable that both unemployment and underemployment are higher at present than they were in 1976.

2. Social Interactions--The broadening of opportunity to all for such activities as employment, education, appointment to positions of responsibility and authority, etc., is a fairly recent innovation in Peru. Formerly the society consisted of social strata the lowest of which was the Indian and the highest of which was the landed and/or influential gentry of Spanish ancestry. During the period from the early days of Spanish rule until the recent broadening of opportunity, distinct separation of classes of Peruvian society was the accepted and expected method of operation. Remnants of this social behavior pattern still exist and are often displayed in the lack of trust, appreciation and cooperation between the manual laborer, the laborer supervisor, the non-manual subprofessional personnel and the professional or administrative level personnel. Although these problems will most likely be relieved in time, sufficient time has not passed for eradication of these social patterns and the detrimental effects still impact the interaction of the working groups and teams presently working throughout the country. In order to overcome such problems, many projects needlessly include foreign managers whose real purpose becomes that of coordinating efforts of the Peruvian worker classes which are otherwise capable of adequately performing the required tasks.
3. Management Constraints--The present financial constraints and the accompanying close scrutiny of all activities tend to promote extreme caution, and lack of decisiveness and initiative among managers and decisionmakers at the very time that such qualities are most needed. Selection of key personnel based on ability will become increasingly important for the future of the country. The number of possible candidates for such positions is very large compared to the opportunities provided but the number of good candidates for key positions is limited by a lack of depth, experience, and ability. In such critical times only the better should be considered, and only the best of these should be selected in the final analysis. Selections in Peru are not always based on such reasoning.
4. Labor Force Capability--Peruvian manual workers are generally competent, industrious, and eager to work. This includes even the most uneducated and unskilled laborers who, when adequately trained, have proven to be highly motivated and capable of good performance and productivity even under rather severe working conditions. Pride of workmanship and attention to detail do not appear to be a problem. Thus, quality should not be difficult to produce providing adequate training and financial support are provided.

5. Shift of Authority--The funding shortages in Peru have caused an upward movement of policy decision making to higher levels of administration. This is to be expected. Concomitant with this upward movement, however, is the upward movement of technical and administrative authority and responsibility. The net result of the latter shift is that the decision making functions for many technical activities has become overly complex, time consuming and inefficient. As a consequence, middle level technical management has been virtually stripped of meaningful responsibility. Senior level technical management is effectively operating at the middle management level while senior level technical decisions are increasingly being made in the non-technical arena. Long term commitment to such policies could in time erode initiative and dedication, and negate the experience of technical management so that the technical decision making infrastructure will be increasingly inadequate for the needs.
6. Technical Experience--Finally, a primary factor which can be observed in the high technology areas is the lack of experience of all but a select few in regards to the latest techniques, methods, equipment, etc. The reasons for this appears to be twofold. First, the lack of travel funds for the middle level technical professional, and existing government travel restrictions make it virtually impossible for such persons to travel to foreign countries, particularly developed countries, where an opportunity to work with, experience, or even view technical activities in their field could occur. Secondly, the inability to speak and adequately understand non-Spanish languages limits access to and understanding of the latest technical information directly from the source, primarily the developed industrialized nations. A foreign language capability if made a requirement of the technical university programs could provide professional level, technical personnel with the ability to directly read and accurately interpret the technical literature of the countries where high technology is developed and practiced. This capability should greatly enhance the opportunity of professional personnel to compensate for firsthand experience not provided by existing activity in Peru.

G. CONCLUSIONS AND RECOMMENDATIONS

An assured and growing supply of energy will be crucial to the economic and consequently the social and political future of Peru. The planning, design, construction, startup, operation and maintenance of Peru's future energy supply system will depend heavily upon the availability of thousands of technically competent individuals. For many reasons the bulk if not all of the energy sector manpower should be Peruvian. Basic training of this manpower will be a Peruvian responsibility and must, therefore, be factored into the programs of the educational system. Provisions must also be made to supplement the basic training with practical, experience producing activities if overall competence is to be realized.

The most important factor impacting manpower in Peru at the present time is the poor economic condition of the country. Until this condition is improved, few long-term plans can be developed with assurance of scheduled enactment. Projection of the quantity, quality, and timing of manpower requirements will be difficult but must be attempted and revised periodically to insure awareness, if not control, of manpower conditions. During the period of reduced economic activity, specialized training as well as general education should be carried on so that a competent labor base exists to support development when economic conditions improve.

Generally speaking, the existing energy sector manpower would be inadequate for the tasks required under an active, aggressive energy expansion program. An adequate supply of unskilled laborers is available in the national labor pool to supply the unskilled labor needs but many types of semi-skilled and skilled laborers would be in short supply. Although this manpower could be produced by the timely addition of specially designed and adequately supported courses to the programs of the ESEPs, CECAPes, and SENATI, the workers produced would lack the practical experience to perform the required tasks without an extra degree of supervision and direction. Such training of the semi-skilled and skilled workers, however, would require technical teachers with higher technical qualifications than presently exist. Thus, a need to upgrade technical teachers well in advance of anticipated need for semi-skilled and skilled workers would be crucial to an energy expansion program. The requirement for semi-skilled and skilled manual labor supervisors could pose a severe problem. The primary attribute needed by a supervisor is meaningful experience. It is doubtful that a sufficient quantity of experienced supervisors could be obtained from the ranks of existing workers. Thus, a carefully designed and executed program to prequalify existing semi-skilled and skilled workers for supervisory assignment would be required. Although this could be done, it would also need to be started well in advance of the requirement for such supervisors. Training to produce supervisors would primarily consist of programmed assignment to a variety of tasks to increase the individuals background and experience.

A sufficient quantity of subprofessional, non-manual, technical workers (e.g., technicians, designers, draftsmen) could be produced in the ESEPs but the design and development of special energy sector oriented programs would be desirable. Because of the special focus of the training, the energy sector agencies would have to take a very active role in the design, development and probably teaching of many of the courses. Establishment of the curricula would require lead times of at least four years prior to projected need.

The availability of low level professional personnel (i.e., newly graduated engineers, scientists and administrators) is variable. Although academic programs to produce such personnel exist, the number of graduates produced is often low and could be inadequate for the need, particularly in fields which are applicable across the spectrum of general economic activity. At least five (and possibly eight) years could be required to correct the quantitative and qualitative training deficiencies which might exist in the university (and secondary school) programs that produce these graduates.

The primary source of supply for middle and senior level technical staffs is the lower and middle level professional personnel, respectively. Due to the current low level of activity in the energy sector, these ranks are presently quite thin. The quantity of

experience producing activities that are useful for training purposes is minimal. Consequently, the number and quality of potential candidates for future promotion to positions of significant responsibility and authority will be limited. Training opportunities which are specifically applicable to assignments related to modern, state-of-the-art systems (or to systems which have not yet been introduced into Peru) would be meager at best due to the paucity (or nonexistence) of suitable facilities for training purposes. Practical training in modern technology and technical administration may be better learned by studying the latest management techniques and technical developments rather than via on-the-job exposure to outmoded systems and the overly complex, untimely and politically oriented decision making processes currently being practiced. In this case, newly designed training may be more practical and, in fact, more desirable for future needs.

Considering the above, the manpower needs that will require special attention for enactment of an active, aggressive energy expansion program are many and varied. Clearly though, manpower development activities will be required. Foreign technical assistance for training program design, teacher training in the early stages and general transfer of latest technology, will be necessary. Such assistance would be most appropriate if obtained from a developed country where modern technology is established and pertinent training programs already exist. Foreign workers will be needed to supplement the inadequate work force during the initial stages of the energy expansion program. Reduction of the requirement for foreign workers and foreign assistance should be actively planned, however, for economic, social and philosophical reasons. Economically, abatement of the foreign dependency will decrease the nontrivial extra costs paid for such workers and assistance. Socially, abatement of the foreign dependency will increase the number of job opportunities as well as provide more skilled and better paying positions for Peruvians instead of foreigners. Philosophically, abatement of foreign dependency will promote self-sufficiency, self-confidence, initiative, job knowledge and many other desirable national traits which are necessary for national self-determination.

The following are specific recommendations relative to the manpower development which have been identified in the Peru/U.S. Cooperative Energy Assessment.

1. The key factor to be considered in selecting the manpower development activities to be pursued is the specific identification of the types of energy systems and the timing of future facility additions. This information can be best obtained via a well developed energy system expansion plan. Until such planning is done only general statements can be made about manpower needs, and only broad general activities can be planned and executed. The danger of this approach is that needless activities may be designed, developed, and executed while other needed activities are ignored. Identification of future energy facilities by type, sequence and schedule will be important since this will determine to a large extent the level of activity and priority of the manpower development effort. It is recommended, therefore, that energy planning be given a high priority, and that manpower planning be specifically included among the planning tasks of the energy system planners.
2. As long as financial instability and shortage of investment and operating capital persist in Peru, manpower planning efforts will be extremely difficult. Under such conditions, the energy development program will largely become a project

by project activity with the approval of any given project being given just prior to or in some cases after its desirable date of commencement. Such activity is normal when large numbers of necessary projects are forced to compete for inadequate resources. Consequently, tracking the availability of manpower resources can be worthwhile since it allows late decisions to be made with improved assurance that the required manpower resources are truly available. It is recommended, therefore, that special attention be given to energy-related manpower needs and availability, so approved energy projects can be mobilized quickly and efficiently to insure proper use of funds provided.

3. The number of highly trained and experienced personnel needed for key positions of an energy system expansion program will be larger than the number of qualified Peruvian candidates. The ability to provide meaningful training opportunities within Peru--particularly, for the positions involving the latest or totally new technologies--will be inadequate. It is recommended, therefore, that the Peruvian energy agencies assess their needs for key personnel within the framework of their future plans and that the government of Peru request assistance from the developed countries to provide appropriate on-the-job training opportunities and, if necessary, partially support trainees for such key positions.
4. The basic training of semi-skilled, skilled, and subprofessional technical personnel needed for an active, aggressive energy expansion program will be done in the CECAPES, ESEPs and SENATI. All courses pertinent to the energy sector and all specialized curricula specifically offered to train workers for the energy sector should be designed and developed as a cooperative effort between the Ministry of Education (or SENATI) and the energy agencies. It is recommended, therefore, that all energy sector agencies take an active role in the design and development of appropriate courses, and provide assistance and support when necessary to insure that an adequate number of high quality graduates are produced. Similar active involvement and assistance by the energy agencies with CONUP and the universities also appears appropriate and desirable for the basic training of professional level, technical personnel.
5. The professional level, technical personnel, particularly those who prove to be promotable to responsible middle level and senior level positions, should be encouraged to upgrade their education by taking part in the technical training courses, seminars, and conferences sponsored by the international professional societies, international agencies, other governments, etc. Such activities should produce an increase of dedication and interest by the individual and partially compensate for the lack of on-the-job training opportunities and professional exposure due to the present decreased level of technical activities in Peru. It is recommended, therefore, that the restrictive government policies with regards to leaving the country be modified to promote rather than discourage travel for professional reasons. If possible, funds should be provided and allocated in support of such activities, at least for key individuals who can profit to the benefit of the country by the technical exposure. Encouragement and support for the formation of sanctioned chapters of professional societies, technical translation groups, national seminars and conferences, etc., is also recommended.

6. Increased training of larger groups of professional level technical personnel in especially appropriate proven energy technologies; developmental energy technologies; and energy resource exploration, development and production (e.g., small scale hydroelectric construction and operations, energy planning, geothermal, oil development and production) should be considered. Development and presentation of practical (as opposed to academic) training programs as part of the work day when required activity is low or as an after hours supplement during periods of meaningful full employment could greatly assist the transition from low energy sector activity to high energy sector activity. Selection of programs to be developed and presented would depend upon the projection of future energy system needs. It is recommended, therefore, that establishment of such courses be considered and that, if necessary or appropriate, assistance in the design, development, and presentation of the courses be sought from the developed countries which are actively engaged in the field and knowledgeable about the state of the art of the involved technologies.
7. The technical teachers of all countries are generally one step removed from the current technology of the country. In countries like Peru, where technology may be outmoded, the gulf between a teacher's knowledge and the latest information of the subject he teaches can be very great. The continuous upgrading of teachers, particularly in the rapidly developing technical fields such as energy, is most important for the learning experience of their students. It is recommended, therefore, that special training of teachers of energy-related subjects be initiated. If necessary and appropriate, assistance in the design, development, and presentation of such training should be sought from Peruvian energy agencies and the developed countries where the latest information regarding technology exists and where teacher training activities are actively pursued.
8. Design of the program mandated by the Education Reform Decree of 1972 is imaginative and aggressive, but may exceed the funds the central government budget can provide. If this occurs, the tendency may develop to sacrifice the higher levels of training activities to insure that the broader programs of basic education are secured. Such action, although appropriate from a social standpoint, may seriously impact the effectiveness of the long-term energy development of Peru by failing to adequately prepare and supply the specially trained manpower the energy program will require. Since the developed industrialized nations have the experience and firsthand knowledge in modern energy technology, these sources should be protected from excessive requests for assistance to basic education to insure that highly specialized assistance will be provided if and when required. To protect this option, it is recommended that the energy agencies formulate reasonable but meaningful priorities for foreign support of specialized training assistance and make these needs known to the Ministry of Education. Since funding for such activities will probably be sought through foreign loans or grants, a cooperative program between the energy agencies and the foreign funding source to identify special training needs (e.g., programs, equipment, facilities, funds) would be worthwhile and appropriate. The assistance provided by the foreign personnel for the Peruvian manpower development analysis should be most helpful. The report of the cooperative effort should prove useful to both the government of Peru and foreign lenders for their deliberations regarding the requested assistance.

9. It is recommended that increased effort be directed by the energy agencies toward removing the social and cultural obstructions to interclass cooperation within the teams associated with energy development. Promotions and assignments of authority and responsibility should be based on proven ability rather than social, political, or other nonjob-related elements. During the near term, resolution of economic difficulties will require selection of the most competent and dedicated leadership. Selection based on ability made in the energy field will be particularly important for Peru's future development and would provide a meaningful example for the other national programs aimed at broadening the involvement of all social classes in the country's development process.

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CAPITAL AND LABOR RESOURCES REQUIRED TO IMPLEMENT SELECTED ENERGY FUTURES FOR PERU

An Analysis of Peruvian Energy Programs Using the Bechtel Energy Supply Planning Model

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The data base for the Energy Supply Planning Model, upon which this report is based, includes information on "nominal" energy facilities. Although many of the facilities studied here may be similar to facilities actually built by Bechtel, it must be recognized that actual facilities have many characteristics that are specific to the site and the local and general economic conditions at the time of construction. The information herein is generalized for "nominal" facilities and therefore not of the detail or accuracy needed for use at specific plants.

ABSTRACT

Implementation of national energy policy decisions concerning development of new energy sources or expansion of old sources will inevitably result in significant requirements for capital and labor. This report on the implementation requirements of alternative Peruvian energy futures describes an analysis carried out by Bechtel for the U.S. Department of Energy (DOE) as part of the Joint United States/Peru Cooperative Energy Assessment.

The analysis is based on the Bechtel Energy Supply Planning Model (ESPM), which provides a systematic means of calculating, based on user-specified energy development strategies, the total direct resources required to build and operate the energy supply facilities needed to implement the strategies. The ESPM was developed originally for the analysis of energy options in the United States and has been used extensively in supporting the analysis of U.S. energy plans.

Accordingly, a major task in the current study was to adapt the model and data base to conditions appropriate to the Peruvian energy system. The adaptation involved modification of existing ESPM estimates from a U.S. basis to a Peruvian basis using factors for local wage rates, labor project efficiency, expatriate labor usage and cost, import surcharges on capital goods, and other variables. In addition, facility sizes were scaled downward where appropriate. Finally, original engineering estimates were developed for some energy facilities for which the U.S. data did not apply (e.g., certain hydroelectric power plants, electric transmission lines).

At the onset, it was recognized that extensive modification effort would not be possible given the study's limited time and budget. However, it was believed that even the limited effort could provide useful, internally-consistent, estimates of resource requirements. The study results have corroborated this expectation.

The adapted model and data base were applied to a Reference Case energy development program, jointly prepared by the governments of Peru and the United States, as well as to several alternative cases. This made it possible to test the sensitivity of resource requirements to increased use of coal, hydroelectric or renewable energy resources, increased efficiency of energy use, or to combinations of these options for the further reduction of domestic consumption of petroleum.

Cumulative capital costs for the Reference Case for 1978 to 2000 amount to approximately \$U.S. 14 billion (in January 1978 U.S. dollars). About 60% of these requirements are for the electric power sector, (40% for hydroelectric generation) the remainder being almost exclusively for the oil and gas sectors.

Cumulative capital costs for the energy industry vary by only about 3% over the range of the alternative energy cases evaluated.

Construction labor requirements increase from 7,500 person-years in 1977 to 18,100 person-years in 2000, whereas the operation and maintenance requirements increase from 9,600 person-years to 29,200 person-years. The assumptions on the use of foreign labor and material lead to the result that wages for foreign labor and direct purchases of foreign construction materials and equipment equal about 48% of total capital costs.

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PREFACE

This report summarizes a preliminary analysis of the capital and labor resources required to implement alternative Peruvian energy futures. The basis for the study is the Bechtel Energy Supply Planning Model (ESPM), which has been adapted for analysis of the Peruvian energy system from its original focus on the United States.

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Dr. Phiroze J. Nagarvala was the Bechtel Project Manager responsible for relations with the DOE Technical Representative, and for the management, scheduling, control, and supervision of all tasks carried out under this contract. Dr. J. Michael Gallagher had been responsible for this task during the first phase of the effort. Mr. Anthony J. Bowles and Mr. Paul F. Paskert, assisted by Ms. Hala F Asfour, of Bechtel's Cost Engineering Group developed the key assumptions regarding Peruvian energy facility costs and resource requirements. Dr. Ronald Barany, Ms. Andrea L. Watson and Mr. Ralph G. J. Zimmermann of the Energy Systems Group performed the technical tasks required to adapt the model and data base for the Peruvian analysis and perform the scenario analyses.

Section1

INTRODUCTION

Section 1

INTRODUCTION

The Office of International Affairs of the United States Department of Energy (DOE) and the government of Peru convened a team in June 1978 to study issues related to energy supply and demand in Peru. This study is one of a series of cooperative energy assessments between the United States and developing countries. This international energy development program dates to March, 1977, when President Carter directed that a pilot program be initiated to assist individual developing countries in developing their indigenous energy resources. During the initial year of the program the United States and participating countries jointly conducted a preliminary analysis of the participating countries' energy situations. The analysis included an assessment of national energy resources, energy supply and demand options, applicable technologies, environmental effects, and capital, labor and other resource requirements. DOE provided overall planning and management for the program for the U.S. government. Policy guidance was provided by the U.S. Department of State assisted by the Agency for International Development.

Bechtel was invited by the DOE to participate in the Peru energy assessment and to adapt the Bechtel Energy Supply Planning Model (ESPM) to analyze the capital and labor resources required to implement national energy futures developed by the assessment team. The Energy Supply Planning Model (ESPM) provides a quantitative tool useful in analyzing the feasibility and impacts of candidate future energy development programs. Candidate programs typically emphasize various energy conversion and supply options such as offshore oil, coal, synthetic fuels, nuclear or hydroelectric power. The implementation of these various energy options accordingly requires differing amounts of capital and labor.

The ESPM was developed originally for the analysis of energy options in the United States, and the model has been used extensively in the analysis of U.S. energy plans. A major task in the current study, therefore, was to develop a methodology to adapt the model and data base to conditions appropriate to the Peruvian energy system. It was recognized that an extensive modification effort would not be possible given the study's limited time and budget. However, based on other studies of a similar nature, it was believed that the limited effort practicable would provide useful, internally-consistent, estimates of resource requirements. The study results have borne out this expectation.

This report documents the assessment of several Peruvian energy development programs selected by the Peruvian and U.S. governments. It begins with a brief overview of the ESPM model and data base. It then describes the method by which the system was adapted to Peruvian conditions and the results of this adaptation. A Reference Case energy development strategy, developed jointly by the U.S. DOE team and Peruvian authorities, is described. This is followed by a summary of ESPM-derived facility and resource requirements. Finally, the sensitivity of these results to several alternative energy strategies is analyzed.

Section 2

OVERVIEW OF THE MODEL AND DATA BASE

Section 2

OVERVIEW OF THE MODEL AND DATA BASE

The Energy Supply Planning Model incorporates an engineering approach to energy and resources planning. The model provides a systematic means of calculating, based on any user-specified energy development strategy, the total resources required to build and operate the energy supply facilities needed to implement the strategy. The model is specifically designed to facilitate its use in the analysis of energy scenarios, whether these are generated by other models or as elements of national energy policy. With this analytical tool, the feasibility of various proposed strategies can be reviewed in terms of the time, capital, manpower, materials and equipment, and construction schedules required for the necessary energy supply system. To date, the modeling effort has involved an expenditure of approximately 50,000 manhours over the past five years. The model has been extensively documented.¹⁻⁴

¹ "The Energy Supply Planning Model," Volume 1: Model Structure and Use; Volume II-User's Manual and Appendices"; M. Carasso, J. M. Gallagher, K. J. Sharma, J. R. Gayle, R. Barany; Bechtel Corporation; NTIS No. PB-245 382, PB-245 383, August 1975.

^{2,3} "Resource Requirements, Impacts, and Potential Constraints Associated with Various Energy Futures," J. Michael Gallagher, Ronald Barany, Paul F. Paskert, and Ralph G. J. Zimmermann, Bechtel Corporation, NTIS No. PAE-3794-6, 9 March 1977 and August 1978 Annual Reports.

⁴ "Coal in Transition, An Analysis of Coal Development Programs Using the Bechtel Energy Supply Planning Model," J. Michael Gallagher and Ralph G. J. Zimmermann, Bechtel National, Inc., February 1978.

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The model has been used as an energy policy analysis tool by a number of organizations, including the U.S. Department of Energy, the U.S. Department of Commerce, the Electric Power Research Institute, the International Institute of Applied Systems Analysis (IIASA), the U.S. National Academies of Science and Engineering (Committee on Nuclear and Alternative Energy Systems, CONAES), the Workshop on Alternative Energy Strategies (WAES), the World Energy Conference and the World Coal Study.

THE MODEL

Design of the model emphasizes three features:

- Straightforward structure
- User access to decision variables
- Flexibility

Although dimensionally quite large, the model is structurally straightforward. It proceeds from user-specified assumptions for major variables, and explicit assumptions for other variables, through a series of submodels to produce resource requirements. This decomposition into submodels is intended to allow model users a step-by-step specification of decision variables and in so doing to permit testing of the sensitivity of results to these variables.

User access to variables is deliberately emphasized, so that model results represent information derived from user decisions rather than from a decision-making capability endogenous to the model. For most user options, there is a capability to specify user considerations at various levels of detail. To allow this flexibility, reference (or default) specifications exist in the model and become operative only when the user chooses not to exercise his prerogative to specify variables at all levels of detail.

An application of the model follows this procedure:

- The user chooses a candidate future energy mix of interest, for example, for the years 1980, 1985, 1990, and 2000.
- The model then calculates annual schedules of the number of new energy supply facilities of various types that must be brought onstream and operated in order to supply the specified mix.
- Employing user specifications, and at user option, the model then locates the facilities in various regions of the country, allocates fuels derived from the facilities to the regional demands, and calculates transportation facilities required to accomplish the distribution. Alternatively, as for the Peru energy assessment, transportation facility schedules are calculated based on nationally-averaged statistics.
- The model next calculates separately the annual schedules of capital, manpower, material, and equipment resources required for the resulting energy and transportation facilities (from initial commitment to plant startup and for operation and maintenance throughout their economic lives), and for the energy supply system as a whole. These requirements are expressed without regard to the availability of such resources.

Examples of questions for which the model can provide explicit answers include:

- What energy supply and transportation facilities must be constructed to implement a candidate national energy development program? When would they need to be on-line? Committed?
- What direct capital, manpower, equipment, raw materials would be needed? When? Where?
- What would be the requirements of a specific energy industry? (e.g., What will be the manpower requirements of the nuclear power industry in 1983?)

- How different are the requirements of different energy programs? How are the domestic and foreign (or expatriate) requirements for capital and manpower effected by changes in energy programs?

The model can help answer some other questions:

- For which capital, manpower, and material resource categories are future shortages likely to occur unless remedial actions are taken?
- What is the total impact of the resource development strategy on other branches of the national economy?

The following list contains some of the policy questions the model does not presume to answer:

- What should be the national energy program?
- What should be the national hydroelectric program?
- What should be the national energy export program?

THE DATA BASE

A central feature of the Energy Supply Planning Model is its extensive engineering data base which consists of those resources directly required to engineer, construct, start up, operate, and maintain energy supply and transportation facilities. This section describes the data base as developed for the United States; the next section describes its adaptation to Peru. Most of the data are based on in-house engineering estimates by the various divisions of the Bechtel Group of Companies, relying on past construction experience, literature surveys, and industry contacts. This extensive technology data base is frequently used as a primary data source by other energy researchers.

Currently, there are 101 "nominal" energy facilities in the ESPM data base. These facilities include energy extraction, processing, conversion and transportation facilities and were selected to give a comprehensive coverage of the energy supply industry in the United States.

The concept of a nominal facility was used to translate the "101" energy facilities into building blocks with certain energy technology and resource requirements characteristics. A nominal facility represents a "future average" facility in that its resource requirements are intended to be typical of requirements for a facility of that kind and size likely to be under construction in the 1978 to 2000 period. This definition implies that a nominal facility may not be identical to any existing or planned facility but can yield reasonably accurate results over a future time period.

Estimates of resources required for construction of each of the "101" ESPM facilities have been developed for approximately 125 categories of:

- Capital (1978 dollars)
- Manpower
- Materials and equipment (directly purchased)
- Raw materials

Estimates of resources required for annual operation and maintenance have been devised for these facilities in approximately 75 categories.

Due to limitations of time and budget, it was not possible to develop explicit estimates to this degree of detail for Peruvian energy supply facilities. The internal consistency ensured by this detail was carried over to the Peruvian estimates, however, in the adaptation process to be described in later sections of this report.

All U.S. cost estimates were originally developed in 1974 dollars and have recently been escalated to reflect unit cost increases in the detailed production factors (e.g., manpower, materials, and equipment), without consideration of the effects of facility design changes that may have occurred since the original estimates were made (such changes in design are currently being studied for subsequent inclusion). The material and equipment components of both capital cost and annual cost are summarized

in two-digit Bureau of Economic Analysis accounts (e.g., primary iron and steel products, BEA 37) allowing direct use in certain U.S. econometric input-output models to determine the total impacts of ESPM-derived results on other branches of the national economy.

In addition to various cost categories, construction and O&M manpower requirements have been estimated for the major engineering disciplines (e.g., mechanical, electrical), designers and draftsmen, supervisors and managers, and the major manual skills (pipefitters, electricians, carpenters, etc.), and non-skilled workers.

To complement the categories of capital and manpower requirements described above, estimates have been developed for quantities of selected major material and equipment items that must be directly purchased for energy construction projects. Examples of these items include draglines, oil country tubular goods, compressors, and boilers. In addition, since the energy industries are major consumers of many raw materials (steel, aluminum, copper, etc.) it is important to be able to trace the impacts of various energy options on the raw material supply industries. In this case, the data estimates include total construction requirements, whether directly purchased or contained within purchased equipment.

Construction resources are expended at various rates during the construction period. To account for this effect, time-phased data on the percentage of the total resources that are required during each year of the construction project have been developed.

It is important to note that all requirements refer to direct requirements for the construction and operation of facilities. "Ripple" effects through the economy of indirect physical labor and material requirements are excluded. For example, the data base includes the (direct) engineering requirements for the design of a power plant but not the (indirect) engineering requirements associated with the design of purchased equipment (piping, heat exchangers, etc.) included in the power plant.

Section 3

ADAPTATION FOR PERU ANALYSIS

Section 3

ADAPTATION FOR PERU ANALYSIS

The focus of the Energy Supply Planning Model on critical resource issues from an engineering perspective makes it a useful analytical tool in the analysis of international energy development programs. Although the model was developed originally for the analysis of energy options in the United States, it is readily adaptable for analysis of energy situations in other countries. The major benefits of this system to the Peruvian energy assessment are two:

- The energy facilities data base is comprehensive, consistent, current and accessible. It provides a set of engineering information derived under common ground rules for a wide variety of technologies covering the entire energy supply system.
- The ESPM modeling system organizes this data base into an integrated framework which permits rapid and flexible analysis of the sensitivity of capital, labor and other resource requirements to changes in energy policy variables.

A principal task of the Peruvian energy assessment was to adapt the ESPM to the Peruvian energy system. This section describes the methodology and major assumptions used in the adaptation of the model as well as the principal results and some significant limitations on these results. This section concludes with a brief definition of the forty-six nominal energy facilities used in this analysis, together with a summary of the resource requirements associated with the construction and O&M of each facility.

APPROACH

Adaptation of the ESPM for the Peruvian analysis required efforts primarily in four areas:

- Revision of the energy supply system definition (fuels, technologies, transportation system, etc.) to include energy options applicable to Peru
- Modification of the facilities data base using criteria compatible with Peruvian conditions (labor rates, materials, prices, etc.)
- Addition of facilities and data for facilities specific to Peru
- Addition of a computational methodology and information for further financial analysis

Given the short time period allowed by the DOE schedule for completion of the assessment, it was clear that the adaptation must be based on readily available information. Further, since detailed facility cost and resource requirements data for Peru are not readily available, it was determined that the most appropriate approach would involve modification of existing ESPM estimates from a U.S. basis to a Peruvian basis when possible, in order to minimize the number of entirely new estimates for Peruvian facilities. Factors for Peruvian wage rates, project efficiency factors, expatriate labor conditions, import surcharges on capital goods, and other variables could be used to transform the U.S. data. For the facilities requiring new estimates, the new gross estimates could be detailed using the transformed U.S. data.

The existence of the comprehensive U.S. data base in computerized ESPM form made practical the implementation of this approach. Perhaps the most significant advantage of the approach is that the transformed facility data largely retain the relative consistency developed on a U.S. basis across the various energy options.

Two other aspects of the approach merit mention:

- Scaling of facility sizes
- Foreign exchange costs

It was recognized that facility sizes typical of energy projects in the United States would, in many cases, be larger than appropriate for developing countries such as Peru. Thus, it was decided to use parametric scaling equations to adjust resource requirements data for appropriate facilities.

A final methodological note concerns the handling of foreign exchange components of development program requirements. A primary element of resource development strategy for most countries is the encouragement of the use of indigenous labor, industry, and capital in carrying out programs, thereby reducing balance of payment burdens. Therefore, it was decided to provide information for use in analyzing the foreign exchange implications of alternative energy strategies. Accordingly, the ESPM data base was modified by partitioning it into two data sets, the first containing total resource requirements and the second containing the imported component of the total requirements. The "Import" data set contained the costs of direct purchases of foreign labor, materials, equipment and services required for energy facilities. Creation of this data base required assumptions regarding the use of foreign vs. local labor, materials, etc., for the various types of energy facilities. Time did not permit consideration of the (indirect) foreign exchange component of local products.

PERUVIAN INFORMATION ACQUISITION

An important feature of the data development was close contact with Peruvian planning and operational agencies including the Ministry of Energy and Mines, Petroperu and Electroperu. Such contacts were made both early in the study, as well as later, in order to modify and validate earlier results. The early contacts enabled the project team to:

- Develop a first-hand feel for the applicability of the existing ESPM to Peruvian energy conditions
- Determine the most significant areas of modification of the model and data base
- Determine the extent of available construction and operating cost information

- Collect information useful in modifying the existing information to represent conditions in Peru

A preliminary review of the facilities data was carried out prior to the first visit to Peru, and an initial set of Peruvian data was developed to be refined during the country visit. This included changing most units of measure for facilities to metric units (as opposed to energy flows), and developing preliminary values for the most important adaptation parameters. Peruvian energy officials knowledgeable in planning, industry, labor, finance, construction, and power and fuels were interviewed on these issues, and results of the interviews led to refinement of preliminary information.

Labor

The following labor-related questions were developed to guide the interviews in Peru:

- What are the local costs (relative to USA) for labor by discipline?
 - Managerial
 - Technical
 - Clerical
 - Skilled manual
 - Unskilled manual
- What escalation in these rates has occurred recently? Future expectations?
- What picture emerges for the use of expatriate labor- (technical, manual, etc.) in building or operating facilities? What is the government policy here?
- What fraction of projects are built by local vs foreign companies (field vs. home office labor distinctions)?
- Where does expatriate labor come from? What are the relative wage rates of source countries vs. Peru and the USA?

- "Project efficiency" - Compared to a plant in the USA, how many man-years are required for construction? For operation?
- What is the mix of skilled vs. unskilled manual labor on different types of projects?
- Are locally available labor supplies adequate?
- Are training plans likely to change the above?

Materials and Equipment

Questions of significance on materials and equipment included:

- What is the cost of materials and equipment purchased in Peru (relative to world prices)?
- What materials are available locally? In what quantities?
- What is the cost of imported materials and equipment (relative to world prices)?
- What is the government's policy toward importation of materials and equipment?
- Are there bottlenecks in getting items into the country or to project sites (ports, rail lines, etc.)?
- What are the existing and planned capacities for domestic supplier industries?
- What is the escalation rate anticipated for local supplies? How does it compare to worldwide escalation rates?
- Are there Peruvian wholesale price statistics, like those in the USA, which could be used to price materials and equipment?
- How do labor-intensive procedures translate into materials and equipment input reductions?

Capital and Financing

Questions of significance on capital and financing included:

- What are the sources of capital?
 - Within Peru
 - From export credit and world development sources (Exim, World Bank, etc.)
 - From financial institutions on a project financing basis
- What is the expected rate of growth of capital availability if no major change occurs in the present political-financial climate?
- What is the attractiveness of the Peruvian energy field to each source of capital and what are the reasons for this, including susceptibility to changes in political-financial scenarios?
- What are variations in rate of growth or in attractiveness of the Peruvian energy field, if elements of the political-financial climate should change?
- What is the attractiveness of each category of project in the Peruvian energy field for each source of capital (including consideration of self-financing projects, impact of currency fluctuations on the rate of return, protection of the institutions' interest for the duration of financing agreement, etc.)?
- Who owns the facilities? Local vs. foreign vs. government owners? What is the owner's cost of money/capital?
- Who builds the facilities? Local vs. foreign builders?
- Who operates the facilities?
- What has been the past general rate of inflation? Expected future inflation rates?
- How are projects financed (oil company, domestic subsidy, etc.)?

Energy Facility Characteristics

Some questions of significance on energy facility characteristics included:

- What energy technologies and facilities are of interest?
- What are the operating characteristics of these facilities?

- What are reasonable cost estimates for these?
- What are the major differences from identical facilities in USA (cooling towers, sulfur removal, particulate removal, etc.)?
- What other differences are apparent in typical size or process or lifetime?
- What have been the costs of actual projects built or planned (records available)?
- Are there differences in construction lead time from the U.S. experience?
- For what facilities must entirely new estimates be developed to complement the ESPM analysis?

Energy System Parameters

Some questions of significance on energy system parameters included:

- What energy supply technologies are included in the Peruvian energy supply system?
- What are the facility parameters necessary to quantify the system description:
 - Size
 - Capacity factor
 - Process efficiency
 - Transportation characteristics, e.g., annual carrying capabilities, haul lengths
- What facilities in supply chain are domestic vs. foreign (e.g., uranium enrichment)? Will this picture change over time?
- How are process by-products (e.g., associated gas) used?
- What are likely ranges of implementation for supply options? Do these represent a small number of facilities, in which case project-specific data would be desirable, or many facilities, where the "nominal" facility concept would be appropriate?

MAJOR MODIFICATION ASSUMPTIONS

The detailed ESPM listing of labor, materials, equipment, and other costs, coupled with computerization of this detailed data, enabled the separate modification of many facility parameters, which then formed the basis of results aggregated at the facility level. Carrying out the modification required many assumptions regarding differential costs of components in Peru relative to the USA, and local versus foreign sources of the components. The major assumptions utilized are stated below.

General Assumptions

A basic assumption was that future energy projects in Peru would be engineered and constructed according to worldwide standards but that high seismic activity in Peru would be taken into account.* Worldwide standards emphasize the use of capital intensive construction equipment and techniques, as opposed to labor intensive methods.

The significance of this assumption is that the ESPM's U.S. data on the relative mixes of labor and materials quantities for energy facilities can be used for Peruvian facilities. Thus, construction or operation of identical oil refineries in the United States or Peru can be assumed to require identical quantities of capital goods and labor (as adjusted for project efficiency differences). Without this simplifying assumption, modification of the ESPM's data base would require considerably more effort than was available for this study.

Based on discussions held in Peru, this assumption of world standards appears to be reasonable for the major energy projects being considered (e.g., hydro power plants, refineries, transmission lines). However, this would be a less acceptable assumption for more routine civil construction projects, such as housing, or for community-based mini- and micro-hydro projects. For energy facilities with these characteristics, original estimates were made

*An exception to this basic assumption was made for micro- and mini-hydro projects, i.e. they would be built by volunteer labor.

Materials and Equipment

Quantities of materials and equipment required for Peruvian facilities are assumed to be the same as for similar facilities in the United States, as stated above. Determination of the costs of these quantities requires assessment of:

- Local versus foreign source
- Costs of materials and equipment from local sources
- Costs of materials and equipment from imported sources
- Effect of regulations giving preference to Peruvian materials and equipment

Basic materials such as wood products, cement, concrete and steel are currently available from local suppliers in Peru, but this is not the case for much of the finished heavy equipment required.

Uniform national price statistics for capital goods were not available. Peruvian law requires purchase in Peru if local costs are as much as 150% of world prices. It was assumed that locally available materials would be purchased at an average of 125% of ESPM prices.

Despite the availability of many basic materials, the supplies tend to be marginally adequate, with slippage of project construction schedules a possible consequence of over-reliance on local industry. Nevertheless, for this study it was assumed that all products made in Peru will be available in sufficient quantity and quality.

In practice, on the major construction projects most of the required materials and equipment are imported. For these major projects, import tariffs may be waived. Thus, materials and equipment procured from international suppliers in the United States, Europe and Japan can be obtained at the world price plus costs of overseas transportation and local handling and transportation within Peru. The delivered price for imports has been estimated to be 15% above the world F.O.B. price.

These general guidelines were converted to detailed import fractions for about 20 industrial sectors, to develop the costs of materials and equipment for Peruvian facilities at the ESPM level of detail. Separate percentages were estimated for each of the 20 sectors for each facility depending on the detailed bill-of-goods make-up of the requirements as specified in the ESPM data base. Items currently produced in Peru, or expected to be produced in Peru in the near future, were assumed to be procured there. In the long run, the domestic purchase percentages can be expected to become larger.

Table 3-1 shows the fraction of domestic purchase requirements calculated for each type of material and equipment. The cost to Peru for each type of material and equipment is derived from ESPM data as follows:

- Total cost to Peru = ESPM \$ x (1.25 x domestic + 1.15 x import fraction)
- Cost of Imports = ESPM \$ x (1.15 x import fraction)

Labor

There exists in Peru an abundance of local labor. Large numbers of semi-skilled, unskilled, administrative, and clerical workers are readily available. Skilled Peruvian workers are available in moderate numbers in many disciplines, except for highly skilled craft workers such as pipefitters and millwrights. However, there has been limited local experience with large, complex energy projects.

The first step in modifying the ESPM labor data base to Peruvian conditions was to derive adjusted requirements for quantities of labor. As previously stated, the quantities of labor required to build and operate Peruvian energy facilities were assumed to be identical, after adjustment for "project efficiency" factors, to similar facilities in the United States. A project efficiency factor is defined to be the ratio of the number of hours of labor required in Peru, relative to the U.S., for similar

Table 3-1

DOMESTIC COMPONENT OF MATERIALS AND EQUIPMENT PURCHASES (FRACTION OF TOTAL)

	Oil and Gas Wells	Refinery Oil Import, Oil Export	Oil & Gas Transport	Hydro	Micro Hydro	Coal Mines	Railroad	Other Coal Trans- port	Power Plants (Non- Hydro)	Elec. Trans- mission	Elec. Distri- bution
MATERIALS											
Wood Products	.80	.80	—	.80	1.00	.80	.90	1.00	.80	—	1.00
Chemicals and Allied Products	.40	.40	1.00	.90		.65	—	.30	.10	—	
Petroleum Products	.40	.40	1.00	.90		.65	—	.30	.10	—	
Stone, Clay, Glass Products	.80	1.00	1.00	.80		1.00	1.00	1.00	.80	.40	
Primary Iron & Steel Products	0	.10	.10	.90		.40	—	.05	.90	—	
Nonferrous Metals	.80	.80	.40	.50		.80	—	.70	.50	0	
Fabricated Structural Products	.10	.10	.20	.90		.20	0	.30	.40	.90	
Other Fabricated Products	0	0	.05	.90		.10	.90	0	.10	—	
Miscellaneous Materials	.80	.80	—	.80		.80	.90	1.00	.80	—	
EQUIPMENT											
HVAC Equipment and Ductwork	.50	.50	.50	.50		.50	—	.50	.50	—	
Turbines	0	.10	—	0		—	—	—	0	—	
Welding Sets	.15	.15	0	.10		.10	—	.10	.10	—	
Construction Mining Oilfield Equipment	.05	.10	0	.10		0	.10	.10	.10	0	
Materials Handling	0	.15	—	0		0	—	1.00	0	—	
General Industrial Equipment	.15	.15	0	.10		.10	—	.10	.10	—	
Instrumentation and Controls	0	0	0	0		—	—	.20	0	—	
Electrical Equipment	.05	0	0	.05		.30	—	.15	.05	.30	
Fabricated Plate Products	.40	0	.90	0		1.00	—	.90	0	—	
Miscellaneous Equipment	.20	.10	.10	.40		.90	—	.05	.40	—	

projects. Such a factor is a composite of many individual conditions, such as construction equipment availability, laborer work knowledge and ability, job-site conditions, local climate, length of work week, management methods, general economic conditions, and culture. One example of the differences between Peru and the U.S. is a Peruvian law that requires that a person once hired for a construction project cannot be discharged until the end of the project. Such a law precludes staffing policies that call for a reduced labor force as a project nears completion.

Based on Bechtel's experience and judgement, discussions between U.S. DOE project management, the Peruvian authorities and the project team, a number of important factors were jointly agreed upon. These factors included:

- The average percent of total labor employed during the construction and O&M phase of all facilities which would be Peruvian
- The project efficiency factors to be assumed for the various categories of Peruvian and expatriate manpower
- Real wage rates to represent the time period 1979-2000 (for Peruvian and expatriate labor)

The factors agreed upon and used during this study are shown in Table 3-2.

Regarding the use of expatriates, it was assumed that the facilities would be operated and maintained by a predominantly Peruvian work force. Expatriates are used only where absolutely necessary and it was assumed that training programs for Peruvians would be an integral part of the energy development program in order to minimize the employment of expatriates. The engineering and construction of energy facilities is expected to require a somewhat greater use of expatriate labor depending upon type of facility.

The final step necessary to modify the Peruvian labor data was to develop adjusted labor costs, taking into account the use of local vs. foreign

Table 3-2

FACTORS USED TO CONVERT MANPOWER DATA FOR PERU FACILITIES

	<u>Non-Manual Technical</u>	<u>Non-Manual Non-Technical</u>	<u>Manual</u>
PERCENTAGE PERUVIANS			
- Construction	.75	1.00	.90
- Operations and Maintenance	.98	1.00	.98
EFFICIENCY FACTORS			
- Peruvians	1.2	1.2	3.0
- Expatriates	1.2	1.2	1.5
FULL MANPOWER COST (INCLUDES FRINGES)			
Construction (\$/hour)			
● Oil and Gas Wells			
- Peruvians	2.50	1.00	1.25
- Expatriates	16.00	-	8.75
● All Other Construction			
- Peruvians	2.25	1.00	1.15
- Expatriates	14.00	-	8.00
Operations and Maintenance (\$/year)			
- Peruvians	5,180.00	2,300.00	2,650.00
	32,260.00	-	18,340.00

labor and project efficiency factors developed above, and unit labor costs. Unit costs (including all benefits) for Peruvian labor in 1978 are estimated to range from about \$0.65 per hour for non-manual, non-technical personnel, to an average of about \$2 per hour for non-manual technical labor. Labor rates used as representative of the 1979-2000 period are shown in Table 3-2.

These unit costs are roughly 1/7 those prevailing in the United States. Because of a wage freeze over the past few years, current labor costs in Peru can be considered to be depressed with respect to other costs. Future labor costs in real terms are an open question. Without an adequate basis upon which to project real labor costs into the future, this study has assumed that they will remain at approximately their current level. Thus, although Peruvian projects may require on the order of three times as many manhours, resulting overall labor costs are much less than those in the United States.

Of course, the use of foreign labor on Peruvian projects substantially reduces this differential. After inclusion of incentive premiums, unit costs of manual expatriates are expected to be about \$8/hour. The major portion of foreign engineering and field supervision manpower is expected to be provided by developed countries (e.g., United States or West Germany). This cost is estimated to be about \$14/hour.

Other Cost Assumptions

Total construction costs are the sum of labor, materials, equipment, and "other," which includes contractor overhead, fee, and contingency. The exact size of this other cost component varies among the various facility types. Other costs were computed using the same factors as used in the U.S. ESPM data base.

A factor has also been applied to total construction costs to cover working capital costs, as well as general plant and intangible costs. The costs of land and land rights, escalation and interest during construction have not been included in the data base. Escalation and interest during construction are, however, computed by the ESPM in the scenario analyses, based on specified escalation and cost-of-money rates. All costs are stated in January 1978 U.S. dollars.

Many of the foregoing assumptions are based upon the experience of the Bechtel Corporation on the Petroperu Pipeline as well as in the engineering and construction of numerous international energy projects. These assumptions have been reviewed by the U.S. assessment team and officials of the Peruvian Ministry of Energy and Mines, Electroperu and Petroperu.

Facility Scaling

The previous sections describe the assumptions necessary to adjust the resource requirements data to Peruvian conditions for facilities identical in size to those in the United States. For Peruvian facilities considered similar to, but smaller than, corresponding U.S. facilities an additional scaling operation was performed. Resource requirements data were appropriately scaled down for oil refineries, coal mines, and electric generating facilities using oil, gas, coal and nuclear fuels.

The relationship used to express the effect of economies-of-scale on resource costs is $C = ax^b$, where "x" is the size of a facility, "a" is a proportionality constant, "b" is the scale coefficient, and "C" is the resource cost. Separate scale coefficients were developed for manpower, basic materials, other materials and equipment, land, energy and utilities, and miscellaneous costs. The coefficients also varied among facilities.

NEW FACILITY ESTIMATES

Resource requirements data for several energy facilities could not be developed simply by scaling existing data for U.S. facilities. The development of data for these Peru-specific facilities is described below.

The estimates for Diesel Power Plant, Bagasse-Fired Power Plant, Waste-Heat Power Plant, Micro- and Mini-Hydro* and Geothermal Power Plant facilities are essentially new for the overall resources required, with the detailed resources proportional to existing U.S. data. These were estimated on a U.S. basis and converted to Peruvian conditions according to previously described procedures.

Adequate data existed to estimate the Electric Transmission Facilities directly on a Peruvian basis. The hydroelectric facilities were based upon pre-existing Peruvian overall resource estimates. The details were developed from U.S. factors.

For the Micro- and Mini-Hydro facilities the cost of manual labor is not included, having been assumed to be donated by the local populace. As manual labor is a small percentage of the total cost, this assumption is not especially important. In contrast to the other generation facilities, the Micro- and Mini-Hydro facility definitions include a (very basic) transmission and distribution system which accounts for approximately one-half of the total facility costs.

SUMMARY OF PERUVIAN RESOURCE REQUIREMENTS DATA

The range of assumptions described above were integrated into overall sets of construction and operation resource requirements data for Peruvian energy supply facilities. Two parallel data sets were developed, one set describing the total resource requirements to build and operate Peruvian energy facilities, and a second set describing the foreign or import component of those totals. This second or "Imports" data set refers to

*Micro-hydro power plants are defined as having a capacity of less than approximately 100 kWe. Mini-hydro plants have capacities in the range of 100 kWe to 1 mWe.

direct purchases of labor, materials and equipment from foreign sources and can be used to investigate the foreign exchange implications of alternative energy strategies. For the purposes of scenario analysis, a third, "domestic", data set was computed as the difference between the total and imports data sets.

The result of this process was the creation of an extensive data base for Peruvian energy facilities. A description of these facilities is shown later. A summary of the data base is presented in Tables 3-3 through 3-10. Tables 3-3 and 3-4 present the total resource requirements for the construction of energy supply and transportation facilities, respectively. Tables 3-5 and 3-6 present the operation and maintenance resource requirements. Tables 3-7 through 3-10 present the corresponding import components of the total resource requirements.

In the table titles, the term "Capital Resources" in Tables 3-3, 3-4, 3-7, and 3-8 refers to the total resources required for the financing, engineering, construction, and start-up of facilities. The term "Annual Resources" in Tables 3-5, 3-6, 3-9, and 3-10 refers to resources required annually for the operation and maintenance of the facilities.

DATA LIMITATIONS

The approximate nature of the data developed for this study must again be emphasized. The data have been developed to assess order-of-magnitude impacts of Peruvian energy development strategies on national capital and labor requirements. The quality of the data is considered adequate for this purpose. An example of an inappropriate use of this data would be a detailed economic comparison of specific competing projects.

One area in which data uncertainties are particularly large is the future exploration and development of oil and gas fields. This is reflected in the anticipated uncertainty in future well production rates, depths, and finding ratios (i.e., dry well to producer well ratios). Hence, judgement

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY CAPITAL RESOURCES-TOTAL

RESOURCES:

85.	CONSTRUCTION LABOR TOTAL	(THOUSAND MAN-HOURS)
4.	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16.	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30.	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
38.	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	85	4	16	30	38
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)		148,350	0,278	1,687	1,503	0,160
2.	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)		206,850	0,388	1,471	2,297	0,314
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		743,100	1,475	9,836	7,137	0,851
4.	OFFSHORE OIL RECOVERY (525 BPD)		175,631	0,341	3,907	7,567	1,478
7.	LOW-GASOLINE REFINERY (50000 B/D)		11529,297	21,040	33,090	99,059	0,0
11.	ONSHORE OIL EXPORT (50000 B/D)		1913,480	3,273	7,295	20,090	1,755
13.	ONSHORE OIL IMPORT (50000 B/D)		1198,790	1,958	2,935	6,639	0,0
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)		205,650	0,192	1,748	1,625	0,196
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)		262,614	1,278	5,291	7,263	2,017
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)		224,472	0,430	1,813	7,366	0,0
28.	SURFACE COAL MINE (300000 TONNES/Y)		473,616	0,854	0,518	25,894	0,0
51.	OIL-FIRED POWER PLANT (50 MWE)		1464,560	2,512	2,430	9,979	0,0
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)		22,269	0,038	0,037	0,121	0,0
54.	COAL FIRED POWER PLANT (160 MWE)		3337,890	5,782	16,437	66,119	0,0
55.	WASTE HEAT POWER PLANT (50 MWE)		1698,800	2,896	2,936	11,880	0,0
56.	BAGASSE FIRED STEAM POWER PLANT (10 Mw)		623,250	1,168	2,102	7,562	0,0
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		1942,740	3,387	1,868	23,005	0,0
61.	COMBINED CYCLE POWER PLANT (200 MWE)		1714,930	3,378	2,909	32,345	0,0
62.	GAS TURBINE POWER PLANT (15 MWE)		92,787	0,168	0,103	4,088	0,0
63.	DIESEL POWER PLANT (5 MWE)		62,850	0,128	0,353	1,876	0,0
64.	LIGHT WATER REACTOR (LWR) (600 MWE)		18221,297	67,937	55,344	147,688	0,0
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)		4,725	0,006	0,029	0,005	0,0
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)		2336,000	4,619	13,281	18,357	0,0
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)		5789,598	11,087	31,364	58,949	0,0
69.	GEOTHERMAL POWER COMPLEX (50 MWE)		1193,400	2,442	8,883	16,029	0,0
70.	GEOTHERMAL POWER COMPLEX (10 MWE)		303,852	0,622	2,879	5,196	0,0
71.	SOLAR HOT WATER (1000 DWELLINGS)		95,513	0,159	0,386	0,119	0,0

Table 3-3

ENERGY FACILITY CAPITAL RESOURCES-TOTAL

RESOURCES:

39.	OTHER CONSTRUCTOR COSTS	(MILLION JAN 78 DOLLARS)
40.	CONSTRUCTOR COST TOTAL	(MILLION JAN 78 DOLLARS)
50.	CAPITAL COST TOTAL	(MILLION DOLLARS AT END OF CONSTRUCTION)

FACILITY:	RESOURCE NUMBER	39	40	50
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)	0.105	3.733	4.299
2.	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	0.123	4.594	5.294
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	0.559	19.857	22.813
4.	OFFSHORE OIL RECOVERY (525 BPD)	0.801	14.094	16.020
7.	LOW-GASOLINE REFINERY (50000 B/D)	15.702	168.891	194.472
11.	ONSHORE OIL EXPORT (50000 B/D)	3.323	35.736	41.149
13.	ONSHORE OIL IMPORT (50000 B/D)	1.225	12.758	14.645
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)	0.124	3.885	4.503
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)	0.814	16.663	19.065
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)	1.670	11.279	13.799
28.	SURFACE COAL MINE (300000 TONNES/Y)	2.836	30.101	31.811
51.	OIL-FIRED POWER PLANT (50 MWE)	4.399	19.321	21.473
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)	0.048	0.244	0.251
54.	COAL FIRED POWER PLANT (160 MWE)	25.971	114.310	127.049
55.	WASTE HEAT POWER PLANT (90 MWE)	5.207	22.919	25.473
56.	BAGASSE FIRED STEAM POWER PLANT (10 MW)	3.185	14.016	15.578
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	8.746	37.006	41.131
61.	COMBINED CYCLE POWER PLANT (200 MWE)	10.122	48.754	54.187
62.	GAS TURBINE POWER PLANT (15 MWE)	0.647	5.006	5.564
63.	DIESEL POWER PLANT (5 MWE)	0.693	3.049	3.389
64.	LIGHT WATER REACTOR (LWR) (600 MWE)	197.565	468.534	520.751
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)	0.006	0.046	0.051
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)	5.199	41.456	46.077
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)	14.529	115.849	128.761
69.	GEOTHERMAL POWER COMPLEX (50 MWE)	10.416	37.770	41.980
70.	GEOTHERMAL POWER COMPLEX (10 MWE)	3.312	12.008	13.347
71.	SOLAR HOT WATER (1000 DWELLINGS)	0.175	0.839	0.839

Table 3-3 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY CAPITAL RESOURCES - TOTAL

RESOURCES:

85.	CONSTRUCTION LABOR TOTAL	(THOUSAND MAN-HOURS)
4.	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16.	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30.	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
38.	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)

Table 3-4

FACILITY:		RESOURCE NUMBER	85	4	16	30	38
1.	CRUDE OIL PIPELINE (800 MB/D, 241 KM)		2457,000	4,436	43,363	15,985	0,0
3.	OIL TANKER (90,000 DWT; 620,000 B)		0,0	0,0	0,0	50,716	0,0
4.	OIL BARGES (90,000 BBL)		0,0	0,0	0,0	5,138	0,0
5.	OIL TANK TRUCK (226 BBL)		0,0	0,0	0,0	0,108	0,0
6.	PRODUCTS PIPELINE (70 MB/D, 161 KM)		824,700	1,423	7,229	6,609	0,0
7.	HOT OIL PIPELINE (40 MB/D, 80 KM)		534,900	0,911	7,525	4,805	0,0
8.	REFINED PRODUCTS BULK STATION (69 MB/D)		300,750	0,550	1,987	4,695	0,0
9.	RAIL LINE (64 KM, SINGLE TRACK)		1077,750	2,371	14,691	4,302	0,0
10.	MIXED TRAIN (6554 TONNES)		0,0	0,0	0,0	5,412	0,0
11.	COAL UNIT TRAIN (9525 TONNES)		0,0	0,0	0,0	9,077	0,0
15.	COAL BARGES (19,051 TONNES)		0,0	0,0	0,0	5,921	0,0
16.	COAL TRUCK (22,7 TONNES)		0,0	0,0	0,0	0,076	0,0
17.	GAS PIPELINE (0,02463 CU KM/D, 241 KM)		2457,000	4,436	46,023	19,259	0,0
18.	GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		426,583	0,745	3,431	1,354	0,0
20.	LNG TANKER (0,07362 CU KM)		0,0	0,0	0,0	166,437	0,0
21.	60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		114,912	0,205	1,961	0,144	0,0
22.	138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		480,917	0,857	8,321	0,598	0,0
23.	220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		1130,600	1,917	20,079	1,449	0,0
26.	ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		85,709	0,160	0,253	0,294	0,0

Table 3-4

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY CAPITAL RESOURCES - TOTAL

RESOURCES:

39, OTHER CONSTRUCTOR COSTS (MILLION JAN 78 DOLLARS)
 40, CONSTRUCTOR COST TOTAL (MILLION JAN 78 DOLLARS)
 50, CAPITAL COST TOTAL (MILLION DOLLARS AT END OF CONSTRUCTION)

FACILITY:	RESOURCE NUMBER	39	40	50
1. CRUDE OIL PIPELINE (800 MB/D, 241 KM)		6,372	70,157	80,783
3. OIL TANKER (90,000 DWT, 620,000 B)		1,521	52,238	60,168
4. OIL BARGES (90,000 BBL)		0,154	5,293	6,096
5. OIL TANK TRUCK (226 BBL)		0,003	0,111	0,131
6. PRODUCTS PIPELINE (70 MB/D, 161 KM)		1,568	16,829	19,387
7. HOT OIL PIPELINE (40 MB/D, 80 KM)		1,312	14,554	16,758
8. REFINED PRODUCTS BULK STATION (69 MB/D)		0,699	7,931	9,132
9. RAIL LINE (64 KM, SINGLE TRACK)		5,168	26,533	36,293
10. MIXED TRAIN (6554 TONNES)		0,162	5,574	6,421
11. COAL UNIT TRAIN (9525 TONNES)		0,272	9,349	10,769
15. COAL BARGES (19,051 TONNES)		0,178	6,099	7,025
16. COAL TRUCK (22,7 TONNES)		0,002	0,079	0,091
17. GAS PIPELINE (0,02463 CU KM/D, 241 KM)		2,097	71,815	83,450
18. GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		0,740	6,270	7,220
20. LNG TANKER (0,07362 CU KM)		4,993	171,430	197,456
21. 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		0,852	3,161	3,514
22. 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		3,604	13,381	14,872
23. 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		8,644	32,090	35,666
26. ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0,327	1,034	1,149

3-21

Table 3-4 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY ANNUAL RESOURCES - TOTAL

RESOURCES:

90.	LABOR TOTAL	(MAN-YEARS)
4.	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16.	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30.	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
34.	UTILITIES TOTAL	(MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	90	4	16	30	34
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)		7,955	0.025	0.007	0.024	0.0
2.	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)		5,928	0.019	0.035	0.092	0.0
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		69,353	0.217	0.054	0.187	0.0
4.	OFFSHORE OIL RECOVERY (525 BPD)		7,203	0.023	0.028	0.087	0.0
7.	LOW-GASOLINE REFINERY (50000 B/D)		473,625	1.504	4.072	2.373	1.771
11.	ONSHORE OIL EXPORT (50000 B/D)		55,275	0.174	0.233	1.147	0.037
13.	ONSHORE OIL IMPORT (50000 B/D)		58,443	0.182	0.179	0.267	0.011
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)		9,380	0.029	0.022	0.026	0.000
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)		10,321	0.032	0.053	0.113	0.001
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)		489,961	1.440	1.381	2.998	0.172
28.	SURFACE COAL MINE (300000 TONNES/Y)		193,993	0.589	0.435	0.568	0.074
51.	OIL-FIRED POWER PLANT (50 MWE)		53,071	0.164	0.227	0.232	0.000
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)		109,321	0.339	0.434	0.328	0.002
54.	COAL FIRED POWER PLANT (160 MWE)		89,727	0.278	0.523	0.388	0.001
55.	WASTE HEAT POWER PLANT (50 MWE)		38,445	0.120	0.191	0.117	0.001
58.	BAGASSE FIRED STEAM POWER PLANT (10 MW)		22,338	0.069	0.111	0.068	0.001
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		75,025	0.233	0.305	0.411	0.0
61.	COMBINED CYCLE POWER PLANT (200 MWE)		60,057	0.186	0.413	0.825	0.003
62.	GAS TURBINE POWER PLANT (15 MWE)		2,839	0.010	0.019	0.049	0.0
63.	DIESEL POWER PLANT (5 MWE)		21,627	0.067	0.0	0.0	0.0
64.	LIGHT WATER REACTOR (LWR) (600 MWE)		165,445	1.547	1.758	1.305	0.0
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)		0.0	0.0	0.0	0.0	0.0
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)		4,723	0.014	0.011	0.049	0.0
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)		28,338	0.085	0.069	0.296	0.0
69.	GEOTHERMAL POWER COMPLEX (50 MWE)		68,747	0.206	0.144	0.097	0.0
70.	GEOTHERMAL POWER COMPLEX (10 MWE)		22,283	0.067	0.047	0.031	0.0
71.	SOLAR HOT WATER (1000 DWELLINGS)		14,769	0.043	0.011	0.039	0.0

Table 3-5

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY ANNUAL RESOURCES - TOTAL

RESOURCES:

38. SERVICES & MISCELLANEOUS (MILLION JAN 78 DOLLARS)
41. ANNUAL OPERATING COST (EX FUEL) (MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	38	41
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)		0.017	0.072
2.	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)		0.043	0.189
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		0.136	0.593
4.	OFFSHORE OIL RECOVERY (525 BPD)		0.041	0.178
7.	LOW-GASOLINE REFINERY (50000 B/D)		0.456	10.175
11.	ONSHORE OIL EXPORT (50000 B/D)		0.373	1.963
13.	ONSHORE OIL IMPORT (50000 B/D)		0.246	0.886
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)		0.023	0.100
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)		0.059	0.258
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)		1.078	7.069
28.	SURFACE COAL MINE (300000 TONNES/Y)		0.300	1.966
51.	OIL-FIRED POWER PLANT (50 MWE)		0.129	0.754
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)		0.229	1.333
54.	COAL FIRED POWER PLANT (160 MWE)		0.247	1.438
55.	WASTE HEAT POWER PLANT (50 MWE)		0.089	0.517
56.	BAGASSE FIRED STEAM POWER PLANT (10 MW)		0.052	0.301
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		0.197	1.146
61.	COMBINED CYCLE POWER PLANT (200 MWE)		0.296	1.723
62.	GAS TURBINE POWER PLANT (15 MWE)		0.016	0.094
63.	DIESEL POWER PLANT (5 MWE)		0.014	0.081
64.	LIGHT WATER REACTOR (LWR) (600 MWE)		1.015	5.625
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 KWE)		0.0	0.0
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)		0.029	0.104
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)		0.159	0.609
69.	GEOTHERMAL POWER COMPLEX (50 MWE)		0.121	0.568
70.	GEOTHERMAL POWER COMPLEX (10 MWE)		0.039	0.184
71.	SOLAR HOT WATER (1000 DWELLINGS)		0.0	0.092

Table 3-5 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY ANNUAL RESOURCES - TOTAL

RESOURCES:

90,	LABOR TOTAL	(MAN-YEARS)
4,	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16,	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30,	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
34,	UTILITIES TOTAL	(MILLION JAN 78 DOLLARS)

FACILITY:	RESOURCE NUMBER	90	4	16	30	34
1, CRUDE OIL PIPELINE (800 MB/D, 241 KM)		47.232	0.159	0.131	0.048	4.062
3, OIL TANKER (90,000 DWT, 620,000 B)		187.113	0.567	4.553	0.078	0.005
4, OIL BARGES (90,000 BBL)		67.470	0.217	0.770	0.055	0.001
5, OIL TANK TRUCK (226 BBL)		5.546	0.017	0.011	0.011	0.000
6, PRODUCTS PIPELINE (70 MB/D, 161 KM)		33.207	0.130	0.084	0.021	0.083
7, HOT OIL PIPELINE (40 MB/D, 80 KM)		40.898	0.129	0.054	0.040	0.150
8, REFINED PRODUCTS BULK STATION (69 MB/D)		23.137	0.074	0.015	0.019	0.018
9, RAIL LINE (64 KM, SINGLE TRACK)		66.943	0.212	0.131	0.079	0.005
10, MIXED TRAIN (6554 TONNES)		32.984	0.099	0.172	0.092	0.0
11, COAL UNIT TRAIN (9525 TONNES)		381.642	1.146	1.910	1.011	0.0
15, COAL BARGES (19,051 TONNES)		68.138	0.219	0.715	0.025	0.001
16, COAL TRUCK (22.7 TONNES)		5.972	0.018	0.013	0.021	0.000
17, GAS PIPELINE (0.02463 CU KM/D, 241 KM)		52.657	0.186	0.067	0.437	0.004
18, GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		65.172	0.200	0.179	0.040	0.0
20, LNG TANKER (0.07362 CU KM)		218.295	0.670	6.066	0.093	0.005
21, 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		1.025	0.003	0.003	0.001	0.0
22, 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		4.349	0.014	0.014	0.003	0.0
23, 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		10.489	0.033	0.035	0.007	0.0
26, ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		8.319	0.025	0.010	0.015	0.0

Table 3-6

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY ANNUAL RESOURCES - TOTAL

RESOURCES:

38, SERVICES & MISCELLANEOUS (MILLION JAN 78 DOLLARS)
41, ANNUAL OPERATING COST (EX FUEL) (MILLION JAN 78 DOLLARS)

FACILITY:	RESOURCE NUMBER	38	41
1. CRUDE OIL PIPELINE (800 MB/D, 241 KM)		1.687	6.088
3. OIL TANKER (90,000 DWT; 620,000 B)		0.241	5.444
4. OIL BARGES (90,000 BBL)		0.048	1.091
5. OIL TANK TRUCK (226 BBL)		0.002	0.040
6. PRODUCTS PIPELINE (70 MB/D, 161 KM)		0.118	0.437
7. HOT OIL PIPELINE (40 MB/D, 80 KM)		0.134	0.507
8. REFINED PRODUCTS BULK STATION (69 MB/D)		0.006	0.132
9. RAIL LINE (64 KM, SINGLE TRACK)		0.020	0.448
10. MIXED TRAIN (6554 TONNES)		0.017	0.379
11. COAL UNIT TRAIN (9525 TONNES)		0.191	4.258
15. COAL BARGES (19,051 TONNES)		0.045	1.006
16. COAL TRUCK (22.7 TONNES)		0.002	0.054
17. GAS PIPELINE (0.02463 CU KM/D, 241 KM)		0.267	0.962
18. GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		0.097	0.517
20. LNG TANKER (0.07362 CU KM)		0.321	7.154
21. 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		0.002	0.010
22. 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		0.010	0.041
23. 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		0.024	0.099
26. ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0.013	0.063

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Table 3-6 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY CAPITAL RESOURCES-IMPORTS

RESOURCES:

4.	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16.	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30.	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
38.	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)
39.	OTHER CONSTRUCTOR COSTS	(MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	4	16	30	38	39
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)		0.110	1.439	1.331	0.121	0.079
2.	ONSHORE SECONDARY OIL RECOVERY (.913 MBPD)		0.152	1.152	1.969	0.236	0.092
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		0.542	5.479	6.476	0.639	0.420
4.	OFFSHORE OIL RECOVERY (525 BPD)		0.140	3.369	6.802	1.183	0.624
7.	LOW-GASOLINE REFINERY (50000 B/D)		7.891	25.443	92.414	0.0	11.920
11.	ONSHORE OIL EXPORT (50000 B/D)		1.126	5.727	18.683	1.330	2.519
13.	ONSHORE OIL IMPORT (50000 B/D)		0.627	2.314	6.262	0.0	0.968
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)		0.152	1.457	1.442	0.148	0.094
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)		0.171	4.477	6.816	1.516	0.612
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)		0.171	1.151	6.430	0.0	1.248
28.	SURFACE COAL MINE (300000 TONNES/Y)		0.317	0.246	25.443	0.0	2.133
51.	OIL-FIRED POWER PLANT (50 MWE)		0.860	1.466	9.151	0.0	3.353
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)		0.013	0.025	0.109	0.0	0.037
54.	COAL FIRED POWER PLANT (160 MWE)		2.025	9.278	60.371	0.0	16.486
55.	WASTE HEAT POWER PLANT (50 MWE)		0.991	1.670	11.494	0.0	3.337
56.	BAGASSE FIRED STEAM POWER PLANT (10 MW)		0.453	1.067	7.417	0.0	2.418
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		1.197	1.007	21.180	0.0	6.634
61.	COMBINED CYCLE POWER PLANT (200 MWE)		1.382	1.555	29.704	0.0	7.641
62.	GAS TURBINE POWER PLANT (15 MWE)		0.063	0.058	3.754	0.0	0.487
63.	DIESEL POWER PLANT (5 MWE)		0.054	0.186	1.754	0.0	0.523
64.	LIGHT WATER REACTOR (LWR) (600 MWE)		62.345	29.258	133.161	0.0	122.842
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)		0.0	0.0	0.0	0.0	0.004
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)		1.897	5.390	16.884	0.0	3.939
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)		4.332	13.064	55.211	0.0	10.996
69.	GEOTHERMAL POWER COMPLEX (50 MWE)		1.034	1.397	15.622	0.0	7.862
70.	GEOTHERMAL POWER COMPLEX (10 MWE)		0.264	0.453	5.064	0.0	2.497
71.	SOLAR HOT WATER (1000 DWELLINGS)		0.054	0.220	0.112	0.0	0.141

Table 3-7

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY CAPITAL RESOURCES-IMPORTS

RESOURCES:

40. CONSTRUCTOR COST TOTAL (MILLION JAN 78 DOLLARS)

FACILITY:	RESOURCE NUMBER	40
1. ONSHORE OIL RECOVERY-COASTAL (300 BPD)		3.079
2. ONSHORE SECONDARY OIL RECOVERY (.913 MBPD)		3.602
3. ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		13.556
4. OFFSHORE OIL RECOVERY (525 BPD)		12.117
7. LOW-GASOLINE REFINERY (50000 B/D)		137.668
11. ONSHORE OIL EXPORT (50000 B/D)		29.385
13. ONSHORE OIL IMPORT (50000 B/D)		10.171
19. ONSHORE GAS RECOVERY (141,600 CU M/D)		3.293
21. OFFSHORE GAS RECOVERY (186,900 CU M/D)		13.592
27. UNDERGROUND COAL MINE (300000 TONNES/Y)		9.001
28. SURFACE COAL MINE (300000 TONNES/Y)		28.138
51. OIL-FIRED POWER PLANT (50 MWE)		14.831
52. RECONVERSION OF OIL PLANT TO COAL (100 MWE)		0.183
54. COAL FIRED POWER PLANT (160 MWE)		88.160
55. WASTE HEAT POWER PLANT (50 MWE)		17.493
56. BAGASSE FIRED STEAM POWER PLANT (10 MW)		11.355
59. HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		30.018
61. COMBINED CYCLE POWER PLANT (200 MWE)		40.283
62. GAS TURBINE POWER PLANT (15 MWE)		4.361
63. DIESEL POWER PLANT (5 MWE)		2.518
64. LIGHT WATER REACTOR (LWR) (600 MWE)		347.615
66. MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)		0.004
67. DAM & HYDROELECTRIC POWER PLANT (25 MWE)		28.110
68. DAM & HYDROELECTRIC POWER PLANT (150 MWE)		83.604
69. GEOTHERMAL POWER COMPLEX (50 MWE)		25.920
70. GEOTHERMAL POWER COMPLEX (10 MWE)		8.277
71. SOLAR HOT WATER (1000 DWELLINGS)		0.528

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Table 3-7 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY CAPITAL RESOURCES - IMPUTS

RESOURCES:							
4.	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)					
16.	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)					
30.	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)					
38.	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)					
39.	OTHER CONSTRUCTOR COSTS	(MILLION JAN 78 DOLLARS)					
		RESOURCE NUMBER	4	16	30	38	39
FACILITY:							
1.	CRUDE OIL PIPELINE (800 MB/D, 241 KM)		3,284	36,845	15,652	0.0	4,809
3.	OIL TANKER (90,000 DWT; 620,000 B)		0.0	0.0	43,537	0.0	1,141
4.	OIL BARGES (90,000 BBL)		0.0	0.0	4,585	0.0	0,115
5.	OIL TANK TRUCK (226 BBL)		0.0	0.0	0,097	0.0	0,002
6.	PRODUCTS PIPELINE (70 MB/D, 161 KM)		0,992	5,454	6,441	0.0	1,183
7.	HOT OIL PIPELINE (40 MB/D, 80 KM)		0,645	3,498	4,530	0.0	0,991
8.	REFINED PRODUCTS BULK STATION (69 MB/D)		0,413	1,379	2,253	0.0	0,528
9.	RAIL LINE (64 KM, SINGLE TRACK)		2,154	1,628	1,895	0.0	3,904
10.	MIXED TRAIN (6554 TONNES)		0.0	0.0	5,056	0.0	0,122
11.	COAL UNIT TRAIN (9525 TONNES)		0.0	0.0	8,432	0.0	0,204
15.	COAL BARGES (19,051 TONNES)		0.0	0.0	5,601	0.0	0,133
16.	COAL TRUCK (22,7 TONNES)		0.0	0.0	0,072	0.0	0,002
17.	GAS PIPELINE (0.02463 CU KM/D, 241 KM)		3,284	37,750	15,926	0.0	5,354
18.	GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		0,528	1,998	1,215	0.0	0,563
20.	LNG TANKER (0.07362 CU KM)		0.0	0.0	73,556	0.0	3,785
21.	60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		0,149	1,163	0,144	0.0	0,644
22.	138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		0,624	4,931	0,598	0.0	3,406
23.	220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		1,303	11,880	1,449	0.0	6,535
26.	ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0,124	0.0	0.0	0.0	0,250

Table 3-8

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY CAPITAL RESOURCES - IMPORTS

RESOURCES:

40. CONSTRUCTOR COST TOTAL (MILLION JAN 78 DOLLARS)

FACILITY:	RESOURCE NUMBER	40
1. CRUDE OIL PIPELINE (800 MB/D, 241 KM)		60,591
3. OIL TANKER (90,000 DWT; 620,000 B)		44,678
4. OIL BARGES (90,000 BBL)		4,700
5. OIL TANK TRUCK (226 BBL)		0,099
6. PRODUCTS PIPELINE (70 MB/D, 161 KM)		14,070
7. HOT OIL PIPELINE (40 MB/D, 80 KM)		9,664
8. REFINED PRODUCTS BULK STATION (69 MB/D)		4,573
9. RAIL LINE (64 KM, SINGLE TRACK)		9,582
10. MIXED TRAIN (6554 TONNES)		5,177
11. COAL UNIT TRAIN (9525 TONNES)		8,637
15. COAL BARGES (19,051 TONNES)		5,734
16. COAL TRUCK (22,7 TONNES)		0,074
17. GAS PIPELINE (0,02463 CU KM/D, 241 KM)		62,313
18. GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		4,304
20. LNG TANKER (0,07362 CU KM)		77,301
21. 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		2,100
22. 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		9,560
23. 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		21,167
26. ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0,374

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Table 3-8 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY ANNUAL RESOURCES = IMPORTS

RESOURCES:

4,	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16,	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30,	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
34,	UTILITIES TOTAL	(MILLION JAN 78 DOLLARS)
38,	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)

FACILITY:		4	16	30	34	38
1,	ONSHORE OIL RECOVERY-COASTAL (300 BPD)	0.002	0.004	0.019	0.0	0.004
2,	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	0.001	0.027	0.063	0.0	0.011
3,	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	0.016	0.028	0.148	0.0	0.036
4,	OFFSHORE OIL RECOVERY (525 BPD)	0.002	0.014	0.059	0.0	0.010
7,	LOW-GASOLINE REFINERY (50000 B/D)	0.109	2.466	2.082	0.0	0.116
11,	ONSHORE OIL EXPORT (50000 B/D)	0.012	0.157	1.067	0.0	0.095
13,	ONSHORE OIL IMPORT (50000 B/D)	0.013	0.129	0.242	0.0	0.063
19,	ONSHORE GAS RECOVERY (141,600 CU M/D)	0.002	0.012	0.021	0.0	0.006
21,	OFFSHORE GAS RECOVERY (186,900 CU M/D)	0.002	0.028	0.073	0.0	0.015
27,	UNDERGROUND COAL MINE (300000 TONNES/Y)	0.102	1.041	2.298	0.0	0.279
28,	SURFACE COAL MINE (300000 TONNES/Y)	0.040	0.141	0.274	0.0	0.078
51,	OIL-FIRED POWER PLANT (50 MWE)	0.011	0.139	0.207	0.0	0.033
52,	RECONVERSION OF OIL PLANT TO COAL (100 MWE)	0.024	0.270	0.294	0.0	0.059
54,	COAL FIRED POWER PLANT (160 MWE)	0.020	0.337	0.347	0.0	0.063
55,	WASTE HEAT POWER PLANT (50 MWE)	0.008	0.111	0.105	0.0	0.023
56,	BAGASSE FIRED STEAM POWER PLANT (10 MW)	0.005	0.065	0.061	0.0	0.013
59,	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	0.016	0.174	0.367	0.0	0.050
61,	COMBINED CYCLE POWER PLANT (200 MWE)	0.013	0.316	0.710	0.0	0.075
62,	GAS TURBINE POWER PLANT (15 MWE)	0.001	0.015	0.042	0.0	0.004
63,	DIESEL POWER PLANT (5 MWE)	0.005	0.0	0.0	0.0	0.004
64,	LIGHT WATER REACTOR (LWR) (600 MWE)	1.335	0.917	1.170	0.0	0.753
66,	MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)	0.0	0.0	0.0	0.0	0.0
67,	DAM & HYDROELECTRIC POWER PLANT (25 MWE)	0.001	0.004	0.043	0.0	0.007
68,	DAM & HYDROELECTRIC POWER PLANT (150 MWE)	0.006	0.025	0.261	0.0	0.045
69,	GEO THERMAL POWER COMPLEX (50 MWE)	0.014	0.119	0.085	0.0	0.032
70,	GEO THERMAL POWER COMPLEX (10 MWE)	0.005	0.039	0.027	0.0	0.010
71,	SOLAR HOT WATER (1000 DWELLINGS)	0.003	0.006	0.036	0.0	0.0

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Table 3-9

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

ENERGY FACILITY ANNUAL RESOURCES - IMPORTS

RESOURCES:

41. ANNUAL OPERATING COST (EX FUEL) (MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	41
1.	ONSHORE OIL RECOVERY-COASTAL (300 BPD)		0.028
2.	ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)		0.103
3.	ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)		0.227
4.	OFFSHORE OIL RECOVERY (525 BPD)		0.085
7.	LOW-GASOLINE REFINERY (50000 B/D)		4.773
11.	ONSHORE OIL EXPORT (50000 B/D)		1.332
13.	ONSHORE OIL IMPORT (50000 B/D)		0.447
19.	ONSHORE GAS RECOVERY (141,600 CU M/D)		0.041
21.	OFFSHORE GAS RECOVERY (186,900 CU M/D)		0.118
27.	UNDERGROUND COAL MINE (300000 TONNES/Y)		3.720
28.	SURFACE COAL MINE (300000 TONNES/Y)		0.533
51.	OIL-FIRED POWER PLANT (50 MWE)		0.391
52.	RECONVERSION OF OIL PLANT TO COAL (100 MWE)		0.647
54.	COAL FIRED POWER PLANT (160 MWE)		0.767
55.	WASTE HEAT POWER PLANT (50 MWE)		0.248
56.	BAGASSE FIRED STEAM POWER PLANT (10 MW)		0.144
59.	HIGH BTU GAS-FIRED POWER PLANT (200 MWE)		0.607
61.	COMBINED CYCLE POWER PLANT (200 MWE)		1.114
62.	GAS TURBINE POWER PLANT (15 MWE)		0.062
63.	DIESEL POWER PLANT (5 MWE)		0.009
64.	LIGHT WATER REACTOR (LWR) (600 MWE)		4.176
66.	MICRO HYDROELEC PLANT & DISTRIBUTION (30 KWE)		0.0
67.	DAM & HYDROELECTRIC POWER PLANT (25 MWE)		0.056
68.	DAM & HYDROELECTRIC POWER PLANT (150 MWE)		0.336
69.	GEOTHERMAL POWER COMPLEX (50 MWE)		0.250
70.	GEOTHERMAL POWER COMPLEX (10 MWE)		0.081
71.	SOLAR HOT WATER (1000 DWELLINGS)		0.045

Table 3-9 (Continued)

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY ANNUAL RESOURCES - IMPORTS

RESOURCES:

4,	MANPOWER TOTAL	(MILLION JAN 78 DOLLARS)
16,	MATERIALS TOTAL	(MILLION JAN 78 DOLLARS)
30,	EQUIPMENT TOTAL	(MILLION JAN 78 DOLLARS)
34,	UTILITIES TOTAL	(MILLION JAN 78 DOLLARS)
38,	SERVICES & MISCELLANEOUS	(MILLION JAN 78 DOLLARS)

FACILITY:		RESOURCE NUMBER	4	16	30	34	38
1,	CRUDE OIL PIPELINE (800 MB/D, 241 KM)		0,012	0,117	0,045	0,0	0,023
3,	OIL TANKER (90,000 DWT; 620,000 B)		0,039	0,045	0,078	0,0	0,061
4,	OIL BARGES (90,000 BBL)		0,016	0,012	0,051	0,0	0,012
5,	OIL TANK TRUCK (226 BBL)		0,001	0,0	0,009	0,0	0,000
6,	PRODUCTS PIPELINE (70 MB/D, 161 KM)		0,012	0,071	0,020	0,0	0,030
7,	HOT OIL PIPELINE (40 MB/D, 80 KM)		0,009	0,040	0,039	0,0	0,035
8,	REFINED PRODUCTS BULK STATION (69 MB/D)		0,005	0,012	0,018	0,0	0,001
9,	RAIL LINE (64 KM, SINGLE TRACK)		0,016	0,033	0,0	0,0	0,005
10,	MIXED TRAIN (6554 TONNES)		0,007	0,117	0,087	0,0	0,004
11,	COAL UNIT TRAIN (9525 TONNES)		0,078	1,303	0,955	0,0	0,049
15,	COAL BARGES (19,051 TONNES)		0,016	0,492	0,023	0,0	0,011
16,	COAL TRUCK (22,7 TONNES)		0,001	0,009	0,020	0,0	0,001
17,	GAS PIPELINE (0,02463 CU KM/D, 241 KM)		0,015	0,059	0,158	0,0	0,068
18,	GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		0,014	0,091	0,039	0,0	0,026
20,	LNG TANKER (0,07362 CU KM)		0,047	0,053	0,092	0,0	0,081
21,	60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		0,000	0,002	0,0	0,0	0,001
22,	138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		0,001	0,008	0,0	0,0	0,003
23,	220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		0,002	0,019	0,0	0,0	0,006
26,	ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0,002	0,0	0,0	0,0	0,003

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Table 3-10

RESOURCE REQUIREMENTS IN RESOURCE NUMBER SEQUENCE

05/11/79

TRANSPORTATION FACILITY ANNUAL RESOURCES - IMPORTS

RESOURCES:

41. ANNUAL OPERATING COST (EX FUEL) (MILLION JAN 78 DOLLARS)

FACILITY:	RESOURCE NUMBER	41
1. CRUDE OIL PIPELINE (800 MB/D, 241 KM)		0.598
3. OIL TANKER (90,000 DWT; 620,000 B)		0.223
4. OIL BARGES (90,000 BBL)		0.091
5. OIL TANK TRUCK (226 BBL)		0.011
6. PRODUCTS PIPELINE (70 MB/D, 161 KM)		0.133
7. HOT OIL PIPELINE (40 MB/D, 80 KM)		0.123
8. REFINED PRODUCTS BULK STATION (69 MB/D)		0.036
9. RAIL LINE (64 KM, SINGLE TRACK)		0.054
10. MIXED TRAIN (6554 TONNES)		0.215
11. COAL UNIT TRAIN (9525 TONNES)		2.385
15. COAL BARGES (19,051 TONNES)		0.543
16. COAL TRUCK (22.7 TONNES)		0.031
17. GAS PIPELINE (0.02463 CU KM/D, 241 KM)		0.300
18. GAS DISTRIBUTION FACILITIES (283000 CU MET/D)		0.170
20. LNG TANKER (0.07362 CU KM)		0.273
21. 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)		0.003
22. 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)		0.011
23. 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)		0.028
24. ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)		0.005

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Table 3-10 (Continued)

and existing information on current well parameters was used to estimate the resources required and unit production cost data. Costs for, and the resources required by, the oil and gas production sectors are strongly influenced by several factors, primarily the assumptions for production per day and total well life. Assumptions used for these (and other) parameters are detailed in "Brief Definition of Peruvian Energy Facilities" (pp. 3-36 through 3-42). It should be noted that alternate assumptions could have a major impact on the total cost and resources required.

Specific limitations arose from the short time allowed for the study, which restricted the coverage of energy technologies to those already contained in the ESPM and to a limited number of key Peru-specific facilities. An example of such limitations is that technologies for generation of electric power via solar and wind power were not included.

ADDITIONAL METHODOLOGY ON FINANCIAL ANALYSIS

The availability of financing, both domestic and foreign, could be a major constraint in the development and execution of a long-term energy strategy. In order to better analyze the impact of such financial constraints, a number of modifications were made to the existing ESPM model in order to produce additional financial data. These data include: borrowings to date, borrowings in grace, total debt to date, and total debt service (consisting of separately computed interest and repayment of principal). In computing these data, funds raised ("borrowed") have been defined as being equal to total capital expenditures. No explicit assumptions were made about financing sources, i.e. whether financing would be debt or equity. The data are computed separately for each facility type, based on annual facilities additions schedules, and are computed and reported in both current dollar and real dollar terms.

Current dollar capital costs have been computed using a specified cost escalation rate of seven per cent per year. Real dollar total capital costs, and all other real dollar financial data except borrowings to date,

are computed by deflating the respective current dollar amount using a projected inflation rate of seven per cent per year. Borrowings to date, both in current and real dollar terms, are defined as the cumulative sum of the respective capital costs. Borrowings in grace in a given year include the sum of all construction expenditures which have been made through that year for those projects which will not be completed until later years. In addition to construction expenditures, borrowings in grace also include the computed interest during construction on funds assumed to have been raised to finance the expenditures. Total debt to date in a given year is defined as total capital expenditures (and therefore total borrowing) through the year, minus total principal repayments through that year. In computing these data, borrowings in the initial year, 1977, are defined to include borrowings made in previous years for projects that were not completed until 1977 or later years.

Debt service is computed for each individual project by using a specified cost-of-money and repayment period for the facility type and assuming equal annual payments over the repayment period. Interest in a given year of the project's repayment period is computed by applying the cost-of-money to the outstanding principal.

BRIEF DEFINITIONS OF ENERGY FACILITIES CONSIDERED FOR PERU

E1. Onshore Oil Recovery-Coastal (300 barrels per day)

Newly estimated for Peruvian conditions
15 producing wells - 365 days per year
2 dry holes
Average Depth - 1766 meters
Average facility production over 20 year life is 300 barrels per day
Exponential production decline with 4 year half-life

E2. Onshore Secondary Oil Recovery (300 barrels per day)

Newly estimated for Peruvian conditions
8 of 33 old wells worked over
16 new holes drilled
39 producing wells - 365 days per year
10 water injection wells
Average depth - 1450 meters
Average facility production over 20 year life is 300 barrels per day
Exponential production decline with 5 year half-life

E3. Onshore Oil Recovery - Jungle (3000 barrels per day)

Newly estimated for Peruvian conditions
15 producing wells - 365 days per year
2 dry holes
Average depth - 3850 meters
Average facility production over 20 year life is 3000 barrels per day
Exponential production decline with 3 year half-life

E4. Offshore Oil Recovery (525 barrels per day)

Newly estimated for Peruvian conditions
15 producing wells and 2 dry holes on a platform
in 100 meters of water - 365 days per year
Average depth - 1766 meters
Average facility production over 20 year life is 525 barrels per day
Exponential production decline with 4 year half-life

E7. Low-Gasoline Refinery (50,000 barrels per day)

Scaled down from larger U.S. refinery
345 operating days per year - 25 years
Flexicoking, distillate and gas oil hydrotreating, reforming,
hydrogen production, and sulfur recovery

E11. Onshore Oil Export (50,000 barrels per day)

Scaled down from larger U.S. facility
350 operating days per year - 50 years
Fixed roof tanks included

E13. Onshore Oil Import (50,000 barrels per day)

Scaled down from larger U.S. facility
350 operating days per year - 50 years
Fixed roof tanks included

E19. Onshore Gas Recovery (141,600 cubic meters per day)

Newly estimated for Peruvian conditions
15 producing wells - 365 days per year
2 dry holes
Average depth 1925 meters
Production stated is average for the facility over 20 year life
Includes gathering and production equipment

E21. Offshore Gas Recovery (186,900 cubic meters per day)

Newly estimated for Peruvian conditions
15 producing wells - 365 days per year
2 dry wells
Average depth is 1925 meters
Production stated is average for the facility over 20 year life
Includes production equipment

E27. Underground Coal Mine (300,000 tonnes per year)

Scaled down from larger U.S. coal mine
253 operating days per year - 20 years
Preparation included, room and pillar, onsite transportation;
assumes 1.6 meter seam

E28. Surface Coal Mine (300,000 tonnes per year)

Scaled down from larger U.S. coal mine
253 operating days per year - 20 years
Assumes level 1.9 meter seam, stripping ratio 16:1, 90% recovery;
includes initial stripping for two week's production, mining,
onsite transportation, and processing equipment, preparation
included

E51. Oil-Fired Power Plant (50 megawatts)

Scaled down from larger U.S. plant
365 days per year - 30 years
Uses fuel oil; natural gas is an alternative and light oil an emergency alternative
Has natural draft cooling tower

E52. Reconversion of Oil Power Plant to Coal (100 megawatts)

Scaled down from larger U.S. plant
365 days per year - conversion happens once, plant operates to end of its original life which is 30 years or less.

E54. Coal-Fired Power Plant (160 megawatts)

365 days per year - 30 years
Burns high-Btu coal
Has natural draft cooling tower

E55. Waste Heat Power Plant (50 megawatts)

Newly estimated for Peruvian conditions
Similar to an oil fired power plant but with very large heat exchanger instead of boiler. Heat comes from an industrial furnace such as a steel smelter. No environmental cleanup equipment

E56. Bagasse Fired Steam Power Plant (10 megawatts)

Newly estimated for Peruvian conditions.
Burns oil and bagasse. Colocated with and sized to fit sugar mill. No environmental cleanup equipment

E59. High Btu Gas-Fired Power Plant (200 megawatts)

Scaled down from larger U.S. plant.
365 days per year - 30 years.
Can burn light oil as an emergency alternative.
Has natural draft cooling tower.

E61. Combined Cycle Power Plant (200 megawatts)

Scaled down from larger U.S. plant.
365 days per year - 30 years.
Has 120-megawatt gas turbine and 80 megawatt steam turbine.
Uses natural gas, but can use light oil as an alternate
Has natural draft cooling tower

- E62. Gas Turbine Power Plant (15 megawatts)
Scaled down from larger U.S. plant
Available 365 days per year for 30 years
Uses natural gas but can use light oil as an alternate
- E63. Diesel Power Plant (5 megawatts)
Newly estimated for Peruvian conditions, gas water cooling
and cooling tower.
Has 10,000 barrel fuel tank
- E64. Light Water Reactor Power Plant (600 megawatts)*
Scaled down from larger U.S. plant
365 days per year - 30 years
Has natural draft cooling tower
- E66. Microhydroelectric Plant and Distribution (30 kilowatts)**
Newly estimated for Peruvian conditions
Unskilled work is done by volunteer labor
Includes 1500 meters of 3 wire distribution line
100 meter head height, no dam
- E67. Dam and Hydroelectric Power Plant (25 megawatts)
Newly estimated for Peruvian conditions
Concrete gravity dam with spillway, penstocks and tunnels
High head power plant
- E68. Dam and Hydroelectric Power Plant (150 megawatts)
Newly estimated for Peruvian conditions
Concrete gravity dam with spillway, penstocks and tunnels
High head power plant
- E69. Geothermal Power Complex (50 megawatts)
Newly estimated for Peruvian conditions
18 production wells
7 reinjection wells
Average depth 1220 meters
Two stage plant

*No nuclear power plants were specified in any of the scenarios evaluated.
Facility costs were estimated, however, and are approximately \$780/KWe,
exclusive of owner's costs.

**No separate estimates were made for mini-hydro power plants. In the scenario assessments, mini-hydro power plants were simulated by assuming they would have ten times the capacity of micro-hydro plants (300 kilowatts) but, due to economies of scale, would only have seven times the resource requirements.

E70. Geothermal Power Complex (10 megawatts)

Scaled down from facility E69

E71. Solar Hot Water (1000 dwellings)

Scaled down from larger U.S. installation

ENERGY TRANSPORT FACILITIES

T1. Crude Oil Pipeline (800,000 barrels per day, 241 kilometers)

Same U.S. facility but estimated for Peru

360 operating days per year - 40 years

36-inch diameter

T3. Oil Tanker (90,000 DWT, 620,000 barrels)

Same as U.S. facility but estimated for Peru.

90,000 deadweight long ton ship with 24,500 shaft horsepower power plant. Capacity is 620,000 barrels. It is expected to have a 25-year life.

T4. Oil Barges (90,000 barrels)

Five barges, each having a capacity of 18,000 barrels, total capacity 90,000 barrels, plus a 3,000 horsepower towboat. It is expected to have a 30-year life.

T5. Oil Tank Truck (226 barrels)

Same as U.S. facility but estimated for Peru.

The tractor-trailer rig has a 300-horsepower tractor; trailer has aluminum tank with capacity of 226 barrels. It is expected to have a seven-year life.

T6. Products Pipeline (70 MB/D, 161 kilometers)

Same as U.S. facility but estimated for Peru.

345 operating days per year - 40 years

12-inch diameter, two pump stations

Input and Output: 70,000 barrels of refined products per operating day

T7. Hot Oil Pipeline (40 MB/D, 80 kilometers)

Same as U.S. facility but estimated for Peru.
360 operating days per year - 40 years
12-inch diameter, insulated, two heating stations

T8. Refined Products Bulk Stations (69 MB/D)

Same as U.S. facility but estimated for Peru
345 days per year receiving from pipeline
250 days per year loading trucks, expected 30-year life
Input: 50,000 barrels on each of 345 days per year
Output: 69,000 barrels on each of 250 days per year
500,000-barrel storage capacity, manifolds, loading pumps, 12
double loading racks, metering, and controls

T9. Rail Line (64 kilometers, single track)

Same as U.S. facility but estimated for Peru
40 new miles of single track - expected life 40 years
Includes signals, communications, structures, wooden ties, grading,
ballast, 119-pound per yard rail
This facility is new standard gauge heavy duty lines, not
rehabilitation of existing track

T10. Mixed Train (6554 tonnes)

Same as U.S. facility but estimated for Peru
This train is a composite of those coal cars that are
normally dispatched by railroads in less-than-train load
quantities. It has 85 steel cars, each carrying 85 tons
of coal. There is one 3,000 horsepower locomotive for
every 29.35 cars. Expected life is 30 years. Standard
gauge.

T11. Coal Unit Train (9525 tonnes)

Same as U.S. facility but estimated for Peru.
105 steel cars each carrying 100 tons, average of 6.5 3,000-
horsepower locomotives, 10 spare cars, and 7.5% spare locomotives
in maintenance, in dedicated service with expedited dispatching.

T15. Coal Barges (19,050 tonnes)

Same as U.S. facility but estimated for Peru.
Fifteen barges, each having a capacity of 1,400 tons, total capacity
21,000 tons. One 4,200 horsepower towboat. Expected life is
30 years.

T16. Coal Truck (22.7 tonnes)

Same as U.S. facility but estimated for Peru.
One over-the-road semi-rig of maximum U.S. size carrying 25 tons of coal. Expected life is seven years.

T17. Gas Pipeline (.0246 cubic kilometers/day, 241 kilometers)

Same as U.S. facility but estimated for Peru.
360 operating days per year - 40 years
36-inch diameter
Compressor horsepower is 252 per mile, of which about 32.5% is spare.
Gas from pipeline used to power compressors.

T18. Gas Distribution Facilities (283,000 cubic meters per day)

Scaled down from larger U.S. facility
365 operating days per year - 40 years
Includes main station, four substations, metering and control equipment, city mains, secondary lines, and connection to meters for urban area of about 25,000 population.

T21. 60 kVac Transmission Line (30 megawatts, 100 kilometers)

Newly estimated for Peruvian conditions based upon Electroperu data.

T22. 138 kVac Transmission Line (100 megawatts, 175 kilometers)

Newly estimated for Peruvian conditions based upon Electroperu data.

T23. 220 kVac Transmission Line (250 megawatts, 250 kilometers)

Newly estimated for Peruvian conditions based upon Electroperu data.

T26. Electricity Distribution - Aerial Lines (10 megawatts)

Scaled down from larger U.S. facility

365 days of operation per year - 50 years
5.3 megawatts of power to industrial customers
1.6 megawatts of power to commercial customers
2.0 megawatts of power to residential customers
.9 megawatts of power to losses in system
10.0 megawatts total rated power
Small amount of undergrounding in very dense areas

Section 4
ANALYSIS OF IMPACT OF STRATEGIES
ON RESOURCE REQUIREMENTS

Section 4

ANALYSIS OF IMPACT OF STRATEGIES ON RESOURCE REQUIREMENTS

DESCRIPTION OF THE STRATEGIES

Reference Case

A reference energy consumption/production strategy was developed by the U.S.-Peru energy assessment team in order to examine the future availability of energy resources and technologies based on current policies and practices. Assumptions made concerning economic and energy development are optimistic, with projected annual average growth rates of 3.7% for the economy and 3.8% for domestic energy production (6.2% for oil recovery, 6.3% for hydro). Because this particular strategy is based on current policies and practices, potential resources, e.g. wind, biomass, solar, and geothermal are not included in the Reference Case. The impact of policies promoting these resources is assessed in the alternative strategies which are discussed in a later section.

In the Reference Case, domestic petroleum production rises to about 220 thousand barrels per day* in 1980, primarily from expansion of production in the Amazon region. About 100 thousand barrels per day are available for export. Oil production then declines through 1985 to 170 thousand barrels per day, a level of output sufficient to meet domestic consumption requirements. By the year 2000, domestic petroleum production reaches 318 thousand barrels per day, with about 30 thousand barrels per day of imports required to meet domestic consumption requirements.

Nearly all domestic oil production in 2000 is provided from fields in the Amazon. Production from currently existing onshore coastal fields

*Oil and gas energy flows are discussed in English units in this section.

declines moderately through 1985. Secondary recovery of petroleum from existing onshore coastal fields increases, however, peaking at 33 thousand barrels per day in 1985. Offshore oil production remains constant to 1985. Production from onshore and offshore coastal oil fields then declines exponentially in the 1985-2000 period.

Gas production is projected to decline somewhat to 1985. From 1985 to 2000 production of associated gas from existing fields declines exponentially while new non-associated fields are developed in the Amazon area, increasing production to about 30 billion cubic feet in the year 2000. Peru currently has no domestic coal production. However, in the 1985-2000 period, production from underground mines is projected to rise to 2.2 million tonnes per year. A summary of primary fuel production assumptions adopted by the ESPM is given in table 4-1 for the Reference Case.

A summary of electric generating capacity is shown in Table 4-2. It is based upon schedules developed by the U.S. - Peru energy assessment team. Total generating capacity increases at an average annual rate of 5.6% during the forecast period. This also includes requirements for gas turbine and diesel plants for the "auto-productores"* sector. The latter comprise about 70% of the requirements for fossil-power plants in the year 2000. Requirements for gas turbine and diesel plants are assumed to be in the same proportion as currently existing diesel and combustion turbine plants.

This strategy also assumes the construction of mini-hydro power plants in the villages. Mini-hydro plant capacity is projected to be 45.0 megawatts in 1995 and 112.5 megawatts in 2000.

Alternative Energy Strategies

Five alternative energy strategies were also assessed:

- Increased efficiency

*"Auto-productores" sector refers to industrial generation of electricity.

	1976	1980	1985	2000	ANNUAL GROWTH
DOMESTIC PETROLEUM PRODUCTION	169.50	497.20	382.20	709.90	6.15%
DOMESTIC NATURAL GAS PRODUCTION	20.40	19.30	18.60	29.00	1.48%
DOMESTIC COAL PRODUCTION	0.0	0.0	0.0	64.05	-----
HYDRO-ELECTRIC POWER INPUTS	70.44	101.11	132.87	303.32	6.27%
ENERGY FROM BIOMASS AND BAGASSE	8.71	8.71	11.48	11.48	1.16%
ENERGY FROM FIREWOOD	162.00	175.00	197.20	108.00	-1.68%
DOMESTIC ENERGY PRODUCTION	431.06	801.32	742.35	1225.75	4.45%
IMPORTED COAL	11.00	12.00	24.10	36.05	5.07%
PETROLEUM IMPORTS	96.90	0.0	0.0	63.00	-1.78%
ENERGY IMPORTS	107.90	12.00	24.10	99.05	-0.36%
TOTAL ENERGY EXTRACTION AND IMPORTATION	538.96	813.32	766.45	1324.80	3.82%
TOTAL PETROLEUM EXPORTS	0.0	212.20	0.0	0.0	-----
ENERGY EXPORTS	0.0	212.20	0.0	0.0	-----
PRODUCTION AND IMPORTS FOR DOMESTIC CONSUMPTION	538.96	601.12	766.45	1324.80	3.82%

Table 4-1 Projected Energy Supply Requirements
for the Reference Case

PERU - REFERENCE CASE

P E T R O L E U M

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PETROLEUM SOURCES
VALUES IN MMBO

	1976	1980	1985	2000	AVERAGE ANNUAL GROWTH
OIL RECOVERY (COASTAL)	0.03	0.03	0.02	0.00	-10.03%
OIL RECOVERY (JUNGLE)	0.01	0.15	0.09	0.31	14.68%
SECONDARY OIL RECOVERY	0.0	0.01	0.03	0.0	-----
ONSHORE CRUDE	0.04	0.19	0.14	0.32	8.62%
OFFSHORE CRUDE	0.03	0.03	0.03	0.00	-10.90%
NATURAL GAS LIQUIDS	0.00	0.00	0.00	0.00	-3.75%
DOMESTIC PETROLEUM PRODUCTION	0.08	0.22	0.17	0.32	6.13%
CRUDE IMPORTS	0.04	0.0	0.0	0.03	-1.41%
REFINED PRODUCT IMPORTS	0.00	0.0	0.0	0.0	-----
PETROLEUM IMPORTS	0.04	0.0	0.0	0.03	-1.77%
OIL PRODUCTION AND IMPORTS	0.12	0.22	0.17	0.35	4.53%

CRUDE OIL

DOMESTIC CRUDE	0.07	0.22	0.17	0.32	6.21%
CRUDE IMPORTS	0.04	0.0	0.0	0.03	-1.41%
TOTAL CRUDE	0.11	0.22	0.17	0.35	4.71%
CRUDE TO REFINERIES	0.11	0.13	0.17	0.35	4.71%
CRUDE EXPORTS	0.0	0.10	0.0	0.0	-----
TOTAL CRUDE	0.11	0.22	0.17	0.35	4.71%

AT REFINERIES

CRUDE TO REFINERIES	0.11	0.13	0.17	0.35	4.71%
NGL TO REFINERIES	0.00	0.00	0.00	0.00	-3.75%
CRUDE AND NGL TO REFINERIES	0.12	0.13	0.17	0.35	4.66%
LIGHT PRODUCT REFINERY INPUT	0.0	0.0	0.0	0.0	-----
HEAVY PRODUCT REFINERY INPUT	0.12	0.13	0.17	0.35	4.66%
CRUDE AND NGL TO REFINERIES	0.12	0.13	0.17	0.35	4.66%

CRUDE TRANSPORTATION

OIL PRODUCTION AND IMPORTS	0.12	0.22	0.17	0.35	4.53%
BY PIPELINE	0.12	0.22	0.17	0.35	4.53%
BY BARGE	0.0	0.0	0.0	0.0	-----
BY TANKER	0.14	0.19	0.20	0.40	4.54%
BY TANK TRUCK	0.02	0.04	0.03	0.07	4.53%

Table 4-1 (Continued)

PERU - REFERENCE CASE

N A T U R A L G A S
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04/21/79 RUN 239

NATURAL GAS SOURCES
VALUES IN TCF/Y

	1976	1980	1985	2000	AVERAGE ANNUAL GROWTH
ONSHORE NATURAL GAS	0.01	0.01	0.01	0.02	4.12%
OFFSHORE NATURAL GAS	0.01	0.01	0.01	0.00	-4.87%
DOMESTIC NATURAL GAS	0.02	0.02	0.02	0.03	1.48%

NATURAL GAS USES

NATURAL GAS FOR DOMESTIC USE	0.02	0.02	0.02	0.03	1.48%
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NATURAL GAS TRANSPORTATION

HIGH-BTU GAS PRODUCTION AND IMPORTS	0.02	0.02	0.02	0.03	1.48%
LOSSES IN GAS TRANSMISSION SYSTEM	0.0	0.0	0.0	0.0	-----
HIGH-BTU GAS INTO DISTRIBUTION SYSTEM	0.02	0.02	0.02	0.03	1.48%
LOSSES IN GAS DISTRIBUTION SYSTEM	0.0	0.0	0.0	0.0	-----
HIGH-BTU GAS FOR CONSUMPTION	0.02	0.02	0.02	0.03	1.48%

NATURAL GAS CONSUMPTION

HIGH-BTU GAS FOR ELECTRICITY GENERATION	0.00	0.00	0.00	0.0	-----
HIGH-BTU GAS FOR DIRECT USE	0.02	0.01	0.01	0.03	2.46%
HIGH-BTU GAS FOR CONSUMPTION	0.02	0.02	0.02	0.03	1.48%

FLARED NATURAL GAS

FLARED NATURAL GAS	0.0	0.0	0.0	0.0	-----
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Table 4-1 (Continued)

PERU - REFERENCE CASE

C O A L
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04/21/79 RUN 239

COAL SOURCES

VALUES IN MMTPY

	1976	1980	1985	2000	AVERAGE ANNUAL GROWTH
UNDERGROUND COAL	0.0	0.0	0.0	2.19	-----
SURFACE COAL	0.0	0.0	0.0	0.0	-----
DOMESTIC COAL PRODUCTION	0.0	0.0	0.0	2.19	-----
IMPORTED COAL	0.40	0.44	0.88	1.31	5.07%
COAL PRODUCTION AND IMPORTS	0.40	0.44	0.88	3.51	9.45%

COAL TRANSPORTATION

COAL PRODUCTION AND IMPORTS	0.40	0.44	0.88	3.51	9.45%
BY UNIT TRAIN	0.0	0.0	0.0	0.0	-----
BY MIXED TRAIN	0.04	0.04	0.09	0.35	9.45%
BY SLURRY PIPELINE	0.0	0.0	0.0	0.0	-----
BY COAL BARGE	0.0	0.0	0.0	0.0	-----
BY COAL TRUCK	0.12	0.13	0.26	1.05	9.45%
LOSSES IN COAL TRANSPORTATION	0.00	0.00	0.00	0.00	12.06%
COAL FOR CONSUMPTION	0.40	0.44	0.88	3.51	9.45%

COAL USES

COAL FOR ELECTRICITY GENERATION	0.0	0.0	0.0	1.01	-----
COAL FOR DIRECT USE	0.40	0.44	0.88	2.50	7.92%
COAL FOR DOMESTIC USE	0.40	0.44	0.88	3.51	9.45%
COAL EXPORTS	0.0	0.0	0.0	0.0	-----
COAL FOR CONSUMPTION	0.40	0.44	0.88	3.51	9.45%

Table 4-1 (Continued)

Table 4-2

PROJECTED ELECTRIC GENERATING CAPACITY FOR THE REFERENCE CASE
(in megawatts)

	1976	1980	1985	2000	Average Annual Growth Rate
TOTAL CAPACITY	2530.8	2951.8	4005.1	9273.0	5.56%
Coal Plants	0.0	0.0	0.0	480.0	—
Heat Recovery Power Plants	0.0	0.0	0.0	50.0	—
Oil Steam Plants	317.0	317.0	251.0	301.0	-0.22%
Diesel Power Plants	476.2	473.0	817.8	1216.4	3.98%
Auto-Productores	295.6	295.6	567.4	966.0	5.06%
Central Grid	180.6	177.4	250.4	250.4	1.37%
Gas Turbine Plants	231.8	230.0	397.6	591.5	3.98%
Auto-Productores	87.9	89.9	275.8	469.7	7.23%
Central Grid	143.9	140.1	121.8	121.8	-0.69%
Bagasse Power Plants	85.0	85.0	112.0	112.0	1.16%
Hydro Power Plants	1420.8	1846.8	2426.6	6522.1	6.56%
25 MWe type	145.5	145.5	212.7	293.7	2.97%
150 MWe type	1260.3	1672.0	2168.9	6115.9	6.80%
300 KWe type	15.0	29.3	45.0	112.5	8.76%

- Increased renewables
- Increased hydro
- Increased coal
- Reduced petroleum

Energy production and consumption is assumed to be the same for all cases until 1985. From 1985 to 2000, the impact of the various strategies is reflected on domestic production of energy, imports, and consumption.

In the Increased Efficiency Case, the impact on oil consumption of more efficient end-use devices without relying on other alternative energy sources to achieve this reduction, is assessed. Thus, the requirements for crude oil imports are eliminated and domestic oil production declines by 2% from the Reference Case. There is also a small (2%) increase in hydro power plant output in this case, due to increased utilization. However, the costs of increased efficiency of end-use utilization and conservation by end-use devices were not included in this assessment.

In the Increased Renewables Case, the increased use of renewable energy resources as a substitute for petroleum is assessed. This results in a 67% decline in oil import levels and a 2% decline in oil used for electricity production.

Combustion turbines and diesel plant capacity in the auto-productores sector is reduced by 2%. In this case, 60 megawatts of geothermal capacity, about 20 megawatts of solar and wind power capacity, and 40 megawatts of wood gasification capacity is brought on-line. However, capital and labor requirements related to solar, wind, and power from wood gasification were not calculated by the ESPM for this assessment. Approximately 84,000 dwellings are projected to be using solar hot water heating by the year 2000. Projected uses of charcoal, alcohol, and biogas in this case were not assessed because cost data for these facilities were not available. Though capital and labor requirements for these uses were not explicitly considered, the total costs are presumably relatively minor and would not affect the overall results.

NOTE 4-8

The Reduced Petroleum strategy identified in this section has been designated Combined Strategies in the Main Report.

In the Increased Hydro Case, the use of electricity is emphasized by an increased development of Peru's large potential for hydroelectricity. It is projected that hydroelectric capacity will be expanded by 24% over levels in the Reference Case. It is assumed that increased hydro power from the central grid will displace oil consumed by combustion turbines and diesel plants in the auto-productores sector, resulting in a 13% reduction in combustion turbine capacity and a 26% reduction in diesel capacity. Oil import levels are reduced by 85% in this case.

In the Increased Coal Case, the use of coal in industry as a replacement for petroleum is emphasized. Domestic coal production is increased by over 40%, and imports of crude oil are reduced by 42% when compared to the Reference Case.

The Reduced Petroleum Case assesses the impact on petroleum demand effected by a combination of the above strategies. Petroleum consumption is reduced by one-third, eliminating the requirements for crude oil imports and reducing domestic petroleum production by 22.5%. Coal production is increased by 28%, and the use of hydro for electric power is increased by 24% over the Reference Case. Two percent of the diesel and combustion turbine generation capacity for the auto-productores sector is replaced by hydro power from the grid.

A summary of changes in energy production and consumption levels for each case as developed by the ESPM is given in Table 4-3.

FACILITY REQUIREMENTS

Requirements for "nominal" energy supply and transportation facilities have been derived for the six cases. The annual schedules of facilities required to be built during the forecast period for the Reference Case are presented in Table 4-4. The schedules take into account facilities which may be required to replace existing facilities (using explicit assumptions about facility lifetimes), and additional facilities which

Table 4-3

IMPACT OF ALTERNATIVE ENERGY STRATEGIES ON ENERGY PRODUCTION
AND CONSUMPTION IN THE YEAR 2000

	Reference Case Output	Increased Efficiency Output	Change	Increased Renewables Output	Change	Increased Hydro Output	Change	Increased Coal Output	Change	Reduced Petroleum Output	Change
Domestic Oil Production (in MBPD)	318.0	306.3	-11.7	318.0	-	318.0	-	318.0	-	242.5	-75.5
Crude Oil Imports (in MBPD)	28.2	-	-28.2	18.8	-9.4	4.1	-24.1	16.8	-11.4	-	-28.2
Domestic Coal Production (in MMTFY)	2.2	2.2	-	2.2	-	2.2	-	3.1	+9	2.8	+6
Solar Hot Water (in thousand dwellings)	-	-	-	84.0	+84.0	-	-	-	-	84.0	+84.0
Electric Generating Capacity (in MWe)											
Hydro	6522.1	6666.0	+143.9	6522.1	-	8061.6	+1539.5	6522.1	-	8061.6	+1539.5
25 MWe	293.7	300.3	+6.6	-	-	364.2	+70.5	293.7	-	364.2	+70.5
150 MWe	6115.9	6253.2	+137.3	6115.9	-	7584.9	+1469.0	6115.9	-	7584.9	+1469.0
Mini and Micro	112.5	112.5	-	112.5	-	112.5	-	112.5	-	112.5	-
Combustion Turbine	591.5	591.5	-	578.7	-12.8	282.5	-309.0	591.5	-	578.7	-12.8
Diesel	1216.4	1216.4	-	1190.1	-26.3	580.8	-635.6	1216.4	-	1190.1	-26.3
Geothermal	-	-	-	60.0	+60.0	-	-	-	-	60.0	+60.0

are needed to meet growth in energy demand. Oil and gas production facility requirements assume an average production over the lifetime of a well and take into account initial production and the rate of decline of production typically exhibited by a well. Oil production per well is assumed to decline exponentially with a half-life varying from 3 to 5 years depending on the location of the well and method of recovery. The annual schedules of electric power plants and transmission lines reflect project schedules developed by the US-Peru energy assessment team from published Peruvian plans.

Energy transportation facility requirements reflect current Peruvian plans and U.S.-Peru energy assessment team assumptions on pipeline, tanker, and other transportation expansion requirements. Calculation of transportation requirements is subject to more uncertainty than for the energy supply facilities because of assumptions made concerning use of competing transport modes, average haul lengths and capacity for each mode.

Because of the nominal facility concept, the estimated facility expansion schedules may not exactly match current Peruvian plans. The major reason for this difference is that actual facility sizes may differ from nominal sizes, and therefore expansion schedules may differ. However, it can be expected that, on the average, resource requirements calculated from the estimated schedule will adequately approximate requirements associated with the various strategies.

In order to take into account construction in progress, energy-related facility requirements between 2000 and 2010 are also estimated. Total construction resource requirements for the year 2000 assume continued energy growth for the period 2000-2010 as shown in Table 4-4. For facilities for which construction schedules are not specified directly, model algorithms extrapolate the schedule beyond 2000 by assuming a rate of construction activity equal to that in the last few years prior to 2000. Since construction schedules were specified directly for the

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

SCHEDULE OF ANNUAL ENERGY FACILITIES ADDITIONS TO SUPPLY FUEL MIX:

PERU - REFERENCE CASE

1977-2010

FACILITY NAME	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL ADDED (1978- 1985)
	TOTALS										
1 ONSHORE OIL RECOVERY-COASTAL (300 BPD)	104.5	3*	3*	3*	3	3	3	2	3	2	22
2 ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	0.0	4*	4*	5*	7	9	11	13	13	12	74
3 ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	3.9	4*	4*	4*	3	3	1	1	0	1	17
4 OFFSHORE OIL RECOVERY (525 BPD)	58.9	3*	3*	3*	2*	3	3	3	3	3	23
7 LOW-GASOLINE REFINERY (50000 B/D)	2.5	1*	0	0	0	0	1	0	0	0	1
11 ONSHORE OIL EXPORT (50000 B/D)	2.8	2*	1*	0	1*	0	0	0	0	0	2
13 ONSHORE OIL IMPORT (50000 B/D)	3.7	0	1*	0	0	0	0	0	0	0	1
19 ONSHORE GAS RECOVERY (141,600 CU M/D)	0.0	0	0	0	0	0	0	0	0	0	0
21 OFFSHORE GAS RECOVERY (186,900 CU M/D)	0.0	0	0	0	0	0	0	0	0	0	0
27 UNDERGROUND COAL MINE (300000 TONNES/Y)	0.0	0	0	0	0	0	0	0	0	0	0
28 SURFACE COAL MINE (300000 TONNES/Y)	0.0	0	0	0	0	0	0	0	0	0	0
51 OIL-FIRED POWER PLANT (50 MWE)	6.3	0	0	0	0	0	0	0	0	0	0
54 COAL FIRED POWER PLANT (160 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
55 WASTE HEAT POWER PLANT (50 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
56 BAGASSE FIRED STEAM POWER PLANT (10 MW)	8.5	0	0	0	0	0	0	0	0	3	3
59 HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
61 COMBINED CYCLE POWER PLANT (200 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
62 GAS TURBINE POWER PLANT (15 MWE)	15.5	0	0	1*	1	2	2	3	3	3	15
63 DIESEL POWER PLANT (5 MWE)	95.2	0	0	2*	7	12	16	18	19	16	90
66 MICRO HYDROELEC PLANT & DISTRIBUTION (30 KWE)	350.0	87*	84*	83*	80	75	71	70	73	77	613
67 DAM & HYDROELECTRIC POWER PLANT (25 MWE)	5.8	0	0	0	0	2*	0	0	0	1	3
68 DAM & HYDROELECTRIC POWER PLANT (150 MWE)	8.4	0	1*	1*	2*	0	0	2	0	1	7
69 GEOTHERMAL POWER COMPLEX (50 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
70 GEOTHERMAL POWER COMPLEX (10 MWE)	0.0	0	0	0	0	0	0	0	0	0	0
71 SOLAR HOT WATER (1000 DWELLINGS)	0.0	0	0	0	0	0	0	0	0	0	0

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4. Projected Schedule of Energy-Related Facility Additions

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SCHEDULE OF ANNUAL ENERGY FACILITIES ADDITIONS TO SUPPLY FUEL MIX:

PERU - REFERENCE CASE

1977-2010

FACILITY NAME	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	TOTAL ADDED (1978- 1996)
1 ONSHORE OIL RECOVERY-COASTAL (300 BPD)	2	2	2	1	2	1	1	1	1	0	1	36
2 ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	11	11	10	10	8	8	7	6	5	3	2	155
3 ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	1	1	1	2	2	2	2	3	3	4	4	42
4 OFFSHORE OIL RECOVERY (525 BPD)	2	2	3	2	1	2	1	1	1	1	0	39
7 LOW-GASOLINE REFINERY (50000 B/D)	1	0	0	1	0	0	1	0	0	1	0	5
11 ONSHORE OIL EXPORT (50000 B/D)	0	0	0	0	0	0	0	0	0	0	0	2
13 ONSHORE OIL IMPORT (50000 B/D)	0	0	0	0	1	0	0	0	1	0	1	4
19 ONSHORE GAS RECOVERY (141,600 CU M/D)	0	0	0	1	0	0	0	0	0	0	1	2
21 OFFSHORE GAS RECOVERY (186,900 CU M/D)	0	0	0	0	0	0	0	0	0	0	0	0
27 UNDERGROUND COAL MINE (300000 TONNES/Y)	0	0	1	0	0	1	0	1	0	1	0	4
28 SURFACE COAL MINE (300000 TONNES/Y)	0	0	0	0	0	0	0	0	0	0	0	0
51 OIL-FIRED POWER PLANT (50 MWE)	0	0	0	0	0	0	0	0	0	0	0	0
54 COAL FIRED POWER PLANT (160 MWE)	0	0	0	0	0	1	2	0	0	0	0	3
55 WASTE HEAT POWER PLANT (50 MWE)	0	0	1	0	0	0	0	0	0	0	0	1
56 BAGASSE FIRED STEAM POWER PLANT (10 MW)	0	0	0	0	0	0	0	0	0	0	0	3
59 HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	0	0	0	0	0	0	0	0	0	0	0	0
61 COMBINED CYCLE POWER PLANT (200 MWE)	0	0	0	0	0	0	0	0	0	0	0	0
62 GAS TURBINE POWER PLANT (15 MWE)	2	2	2	2	2	1	2	1	1	1	1	32
63 DIESEL POWER PLANT (5 MWE)	14	12	12	11	11	9	9	7	7	6	5	193
66 MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)	83	86	89	93	95	99	101	105	109	111	115	1699
67 DAM & HYDROELECTRIC POWER PLANT (25 MWE)	0	1	0	0	0	0	0	0	0	0	2	6
68 DAM & HYDROELECTRIC POWER PLANT (150 MWE)	2	1	1	2	3	0	0	1	2	4	1	24
69 GEOTHERMAL POWER COMPLEX (50 MWE)	0	0	0	0	0	0	0	0	0	0	0	0
70 GEOTHERMAL POWER COMPLEX (10 MWE)	0	0	0	0	0	0	0	0	0	0	0	0
71 SOLAR HOT WATER (1000 DWELLINGS)	0	0	0	0	0	0	0	0	0	0	0	0

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

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SCHEDULE OF ANNUAL ENERGY FACILITIES ADDITIONS TO SUPPLY FUEL MIX:

PERU - REFERENCE CASE

1977-2010

FACILITY NAME	1997	1998	1999	2000	TOTAL ADDED (1978- 2000)
1 ONSHORE OIL RECOVERY-COASTAL (300 BPD)	0	0	0	0	36
2 ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	0	0	0	0	155
3 ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	5	5	6	7	65
4 OFFSHORE OIL RECOVERY (525 BPD)	0	0	0	0	39
7 LOW-GASOLINE REFINERY (50000 B/D)	0	1	0	1	7
11 ONSHORE OIL EXPORT (50000 B/D)	0	0	1	1	4
13 ONSHORE OIL IMPORT (50000 B/D)	0	0	1	0	5
19 ONSHORE GAS RECOVERY (141,600 CU M/D)	0	0	0	1	3
21 OFFSHORE GAS RECOVERY (186,900 CU M/D)	0	0	0	0	0
27 UNDERGROUND COAL MINE (300000 TONNES/Y)	1	1	0	1	7
28 SURFACE COAL MINE (300000 TONNES/Y)	0	0	0	0	0
51 OIL-FIRED POWER PLANT (50 MWE)	1	0	0	0	1
54 COAL FIRED POWER PLANT (160 MWE)	0	0	0	0	3
55 WASTE HEAT POWER PLANT (50 MWE)	0	0	0	0	1
56 BAGASSE FIRED STEAM POWER PLANT (10 MW)	0	0	0	0	3
59 HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	0	0	0	0	0
61 COMBINED CYCLE POWER PLANT (200 MWE)	0	0	0	0	0
62 GAS TURBINE POWER PLANT (15 MWE)	0	1	0	1	34
63 DIESEL POWER PLANT (5 MWE)	5	3	3	1	205
66 MICRO HYDROELEC PLANT & DISTRIBUTION (30 MWE)	117	121	125	127	2189
67 DAM & HYDROELECTRIC POWER PLANT (25 MWE)	0	0	0	0	6
68 DAM & HYDROELECTRIC POWER PLANT (150 MWE)	3	3	2	3	35
69 GEOTHERMAL POWER COMPLEX (50 MWE)	0	0	0	0	0
70 GEOTHERMAL POWER COMPLEX (10 MWE)	0	0	0	0	0
71 SOLAR HOT WATER (1000 DWELLINGS)	0	0	0	0	0

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

SCHEDULE OF ANNUAL ENERGY FACILITIES ADDITIONS TO SUPPLY FUEL MIX: PEP - REFERENCE CASE 1977-2010

FACILITY NAME	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL ADDED (1978- 2010)
1 ONSHORE OIL RECOVERY-COASTAL (300 BPD)	0	0	0	0	0	1	0	0	0	0	37
2 ONSHORE SECONDARY OIL RECOVERY (300 BBL/D)	1	1	1	1	1	1	1	1	1	1	165
3 ONSHORE OIL RECOVERY-JUNGLE (3000 BPD)	7	7	7	7	7	7	7	7	7	7	135
4 OFFSHORE OIL RECOVERY (525 BPD)	0	0	0	0	0	1	0	0	0	0	40
7 LOW-GASOLINE REFINERY (50000 B/D)	0	1	0	1	0	1	0	1	0	1	12
11 ONSHORE OIL EXPORT (50000 B/D)	0	0	1	0	0	1	0	0	1	0	7
13 ONSHORE OIL IMPORT (50000 B/D)	0	0	1	0	0	1	0	0	1	0	8
19 ONSHORE GAS RECOVERY (141,600 CU M/D)	0	0	1	0	0	1	0	0	1	0	6
21 OFFSHORE GAS RECOVERY (186,900 CU M/D)	0	0	0	0	0	0	0	0	0	0	0
27 UNDERGROUND COAL MINE (300000 TONNES/Y)	1	1	1	1	1	1	1	1	1	1	17
28 SURFACE COAL MINE (300000 TONNES/Y)	0	0	0	0	0	0	0	0	0	0	0
51 OIL-FIRED POWER PLANT (50 MWE)	0	0	0	0	0	0	0	0	0	0	1
54 COAL FIRED POWER PLANT (160 MWE)	0	0	0	0	0	0	0	0	0	0	3
55 WASTE HEAT POWER PLANT (50 MWE)	0	0	0	0	0	0	0	0	0	0	1
56 BAGASSE FIRED STEAM POWER PLANT (10 MW)	0	0	0	0	0	0	0	0	0	0	3
59 HIGH BTU GAS-FIRED POWER PLANT (200 MWE)	0	0	0	0	0	0	0	0	0	0	0
61 COMBINED CYCLE POWER PLANT (200 MWE)	0	0	0	0	0	0	0	0	0	0	0
62 GAS TURBINE POWER PLANT (15 MWE)	1	1	1	1	1	1	1	1	1	1	44
63 DIESEL POWER PLANT (5 MWE)	1	1	1	1	1	1	1	1	1	1	215
66 MICRO HYDROELEC PLANT & DISTRIBUTION (30 KWE)	0	0	0	0	0	0	0	0	0	0	2189
67 DAM & HYDROELECTRIC POWER PLANT (25 MWE)	0	0	0	0	0	0	0	0	0	0	6
68 DAM & HYDROELECTRIC POWER PLANT (150 MWE)	3	3	3	3	3	3	3	3	3	3	65
69 GEOTHERMAL POWER COMPLEX (50 MWE)	0	0	0	0	0	0	0	0	0	0	0
70 GEOTHERMAL POWER COMPLEX (10 MWE)	0	0	0	0	0	0	0	0	0	0	0
71 SOLAR HOT WATER (1000 DWELLINGS)	0	0	0	0	0	0	0	0	0	0	0

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

SCHEDULE OF ANNUAL TRANSPORTATION ADDITIONS TO SUPPLY FUEL MIX: PERU - REFERENCE CASE 1977-2010

FACILITY NAME	1976 TOTALS	1977	1978	1979	1980	1981	1982	1983	1984	1985	TOTAL ADDED (1978- 1985)
1 CRUDE OIL PIPELINE (800 MB/D, 241 KM)	0.2	0	0	0	0	0	0	0	0	0	0
3 OIL TANKER (90,000 DWT; 620,000 B)	0.5	0	0	0	0	0	0	0	0	0	0
4 OIL BARGES (90,000 BBL)	0.0	0	0	0	0	0	0	0	0	0	0
5 OIL TANK TRUCK (226 BBL)	180.4	54*	51*	48	45	37	28	26	32	43	310
6 PRODUCTS PIPELINE (70 MB/D, 161 KM)	0.4	0	0	0	0	0	0	0	0	0	0
7 HOT OIL PIPELINE (40 MB/D, 80 KM)	0.0	0	0	0	0	0	0	0	0	0	0
8 REFINED PRODUCTS BULK STATION (69 MB/D)	1.7	0	0	0	0	1	0	0	0	0	1
9 RAIL LINE (64 KM, SINGLE TRACK)	0.0	0	0	0	0	0	0	0	0	0	0
10 MIXED TRAIN (6554 TONNES)	0.0	0	0	0	0	0	0	0	0	0	0
11 COAL UNIT TRAIN (9525 TONNES)	0.0	0	0	0	0	0	0	0	0	0	0
15 COAL BARGES (19,051 TONNES)	0.0	0	0	0	0	0	0	0	0	0	0
16 COAL TRUCK (22.7 TONNES)	2.1	0	1*	0	0	1	1	1	1	1	6
18 GAS DISTRIBUTION FACILITIES (283000 CU MET/D)	4.2	0	0	0	0	0	0	1	0	0	1
21 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)	15.5	0	0	0	1	0	0	0	0	1	2
22 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)	4.2	0	0	0	1	0	1	0	1	0	3
23 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)	4.7	0	0	0	0	3	0	2	1	0	6
26 ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)	132.1	4*	6*	8*	10*	13	15	16	18	19	105

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

SCHEDULE OF ANNUAL TRANSPORTATION ADDITIONS TO SUPPLY FUEL MIX: PERU - REFERENCE CASE 1977-2010

FACILITY NAME	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	TOTAL ADDED (1978- 1996)
1 CRUDE OIL PIPELINE (800 MB/D, 241 KM)	0	0	0	0	0	0	0	0	0	0	0	0
3 OIL TANKER (90,000 DMT, 620,000 B)	1	0	0	0	0	0	0	0	0	0	0	1
4 OIL BARGES (90,000 BBL)	0	0	0	0	0	0	0	0	0	0	0	0
5 OIL TANK TRUCK (226 BBL)	47	46	48	47	49	51	52	55	58	61	65	889
6 PRODUCTS PIPELINE (70 MB/D, 161 KM)	0	0	1	0	0	0	0	0	0	0	0	1
7 HOT OIL PIPELINE (40 MB/D, 80 KM)	0	0	0	0	0	0	0	0	0	0	0	0
8 REFINED PRODUCTS BULK STATION (69 MB/D)	0	1	0	0	0	0	1	0	0	0	1	4
9 RAIL LINE (64 KM, SINGLE TRACK)	0	0	0	0	0	0	0	0	0	0	0	0
10 MIXED TRAIN (6554 TONNES)	0	0	0	0	0	0	0	0	0	0	0	0
11 COAL UNIT TRAIN (9525 TONNES)	0	0	0	0	0	0	0	0	0	0	0	0
15 COAL BARGES (19,051 TONNES)	0	0	0	0	0	0	0	0	0	0	0	0
16 COAL TRUCK (22,7 TONNES)	1	1	2	1	2	2	2	2	2	2	2	25
18 GAS DISTRIBUTION FACILITIES (283000 CU MET/D)	0	0	0	1	0	0	1	0	0	1	0	4
21 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)	0	0	0	0	0	0	1	0	1	0	0	4
22 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)	1	0	1	0	0	0	1	0	1	0	1	8
23 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)	1	0	1	0	1	0	1	1	0	1	1	13
26 ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)	18	20	21	21	22	23	24	25	26	27	28	360

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

RECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

SCHEDULE OF ANNUAL TRANSPORTATION ADDITIONS TO SUPPLY FUEL MIX: PFRU - REFERENCE CASE 1977-2010

FACILITY NAME	1997	1998	1999	2000	TOTAL ADDED (1978- 2000)
1 CRUDE OIL PIPELINE (800 MB/D, 241 KM)	0	0	0	0	0
3 OIL TANKER (90,000 DWT; 620,000 B)	0	0	1	0	2
4 OIL BARGES (90,000 BBL)	0	0	0	0	0
5 OIL TANK TRUCK (226 BBL)	70	74	78	85	1196
6 PRODUCTS PIPELINE (70 MB/D, 161 KM)	0	0	0	0	1
7 HOT OIL PIPELINE (40 MB/D, 80 KM)	0	0	0	0	0
8 REFINED PRODUCTS BULK STATION (69 MB/D)	0	0	0	1	5
9 RAIL LINE (64 KM, SINGLE TRACK)	0	0	0	0	0
10 MIXED TRAIN (6554 TONNES)	0	0	0	0	0
11 COAL UNIT TRAIN (9525 TONNES)	0	0	0	0	0
15 COAL BARGES (19,051 TONNES)	0	0	0	0	0
16 COAL TRUCK (22.7 TONNES)	3	2	3	2	35
18 GAS DISTRIBUTION FACILITIES (283000 CU MET/D)	1	0	0	1	6
21 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)	0	0	1	0	5
22 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)	0	1	0	1	10
23 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)	0	1	1	1	16
26 ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)	28	29	31	31	479

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

SCHEDULE OF ANNUAL TRANSPORTATION ADDITIONS TO SUPPLY FUEL MIX:

PERU - REFERENCE CASE

1977-2010

FACILITY NAME	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	TOTAL ADDED (1978- 2010)
1 CRUDE OIL PIPELINE (800 MB/D, 241 KM)	0	0	0	0	0	0	0	0	0	0	0
3 OIL TANKER (90,000 DWT, 620,000 B)	0	0	0	0	0	1	0	0	0	0	3
4 OIL BARGES (90,000 BBL)	0	0	0	0	0	0	0	0	0	0	0
5 OIL TANK TRUCK (226 BBL)	85	85	85	85	85	85	85	85	85	85	2046
6 PRODUCTS PIPELINE (70 MB/D, 161 KM)	0	0	0	0	0	0	0	0	0	0	1
7 HOT OIL PIPELINE (40 MB/D, 80 KM)	0	0	0	0	0	0	0	0	0	0	0
8 REFINED PRODUCTS BULK STATION (69 MB/D)	0	0	1	0	0	1	0	0	1	0	8
9 RAIL LINE (64 KM, SINGLE TRACK)	0	0	0	0	0	0	0	0	0	0	0
10 MIXED TRAIN (6554 TONNES)	0	0	0	0	0	0	0	0	0	0	0
11 COAL UNIT TRAIN (9525 TONNES)	0	0	0	0	0	0	0	0	0	0	0
15 COAL BARGES (19,051 TONNES)	0	0	0	0	0	0	0	0	0	0	0
16 COAL TRUCK (22.7 TONNES)	2	2	2	2	2	2	2	2	2	2	55
18 GAS DISTRIBUTION FACILITIES (283000 CU MET/D)	0	1	0	1	0	1	0	1	0	1	11
21 60 KVAC TRANSMISSION LINE (30 MWE, 100 KM)	0	1	0	0	1	0	0	1	0	0	8
22 138 KVAC TRANSMISSION LINE (100 MWE, 175 KM)	0	1	0	1	0	1	0	1	0	1	15
23 220 KVAC TRANSMISSION LINE (250 MWE, 250 KM)	1	1	1	1	2	1	2	1	2	1	29
26 ELECTRICITY DISTRIBUTION-AERIAL LINES(10 MWE)	31	31	31	31	31	31	31	31	31	31	789

* - THE CONSTRUCTION SCHEDULE FOR THIS FACILITY IS LONGER THAN THE NUMBER OF YEARS BETWEEN 1977 AND THE ON-LINE DATE.

Table 4-4 (Continued)

most resource-intensive facilities, including hydro-electric power plants and transmission lines, total resource requirements are minimally affected by the use of this algorithm.

Reference Case

A summary of nominal facilities by energy sector for the Reference Case follows.

Oil and Gas Sector:

New oil and gas production capacity of 272,775 bpd and 19.8 million cub ft. per day, respectively, will be required in the 1978-2000 period. This capacity would be provided by:

- 36 new onshore coastal oil recovery facilities at 300 bpd per facility (4% of additional oil production capacity)
- 155 new onshore secondary oil recovery facilities at 300 bpd per facility (17% of additional oil production capacity)
- 65 new onshore jungle oil recovery facilities at 3000 bpd per facility (71% of additional oil production capacity)
- 39 new offshore oil recovery facilities at 525 bpd per facility (8% of additional oil production capacity)
- 3 onshore gas recovery facilities at 186,900 cubic meters per day for each facility

The following additional downstream facilities would also be required:

- 7 low-gasoline refineries of 50,000 bpd each
- 13 oil port facilities of 50,000 bpd each
- Tanker capacity of 1,240,000 barrels
- Products pipeline of 70,000 bpd

Coal Sector:

New coal mining capacity of 2.1 million tonnes per year will be required resulting in the construction of 7 additional underground coal mines with 300,000 tonnes per year capacity. Additional trucking capacity of 194.5 tonnes will also be required.

Electric Power Sector:

Over 7600 megawatts of increased electric generating capacity will be required during the 1978-2000 period in this case. Over 70% of this capacity will be provided from hydro power. The breakdown of the power plants by type follows with the percentage of total capacity indicated in parenthesis:

- 1 oil-fired power plant at 50 MWe (.65%)
- 3 coal-fired power plants at 160 MWe (6.3%)
- 1 waste heat power plant at 50 MWe (.65%)
- 3 bagasse-fired power plants at 10 MWe (.4%)
- 34 combustion turbine power plants at 15 MWe (6.7%)
- 205 diesel power plants at 5 MWe (13.4%)
- 313 mini-hydroelectric power plants at 300 KWe (1.2%)
(includes micro hydro plants on a capacity equivalent basis)
- 6 hydroelectric power plants at 25 MWe (2.0%)
- 35 hydroelectric power plants at 150 MWe (68.7%)

Alternative Cases

A summary of the impacts of the alternative energy strategies on the number of energy-related facility requirements is given in Table 4-5. The largest impacts occur in the Reduced Petroleum Case, where there is a reduction of 30,000 bpd in petroleum production capacity and an increase of 825 megawatts of hydroelectric power capacity. About 600,000 tonnes of increased coal mining capacity will also be required. In the Increased Hydro Case there is a reduction of 3,000 barrels per day of domestic petroleum production capacity, and an equivalent increase of 825 megawatts of hydroelectric power. Combustion turbine and diesel plant capacity is reduced by 180 and 365 megawatts, respectively.

Table 4-5

**IMPACT OF ALTERNATIVE ENERGY STRATEGIES
ON SELECTED ENERGY RELATED FACILITY REQUIREMENTS
(in number of facilities added 1978-2000)**

		Energy Efficiency		Increased Renewables		Increased Hydro		Increased Coal		Reduced Petroleum	
	Reference	No. of Facilities	Change	No. of Facilities	Change	No. of Facilities	Change	No. of Facilities	Change	No. of Facilities	Change
PETROLEUM											
Onshore Oil Recovery-Jungle (3000 BPD)	65	64	-1	65	-	65	-	65	-	55	-10
Low Gasoline Refinery (50,000 BPD)	7	6	-1	6	-1	6	-1	6	-1	4	-3
Onshore Oil Export (50,000 BPD)	4	3	-1	4	-	3	-1	4	-	2	-2
Onshore Oil Import (50,000 BPD)	5	5	-	5	-	5	-	5	-	3	-2
Oil Tanker (90,000 BWT, 620,000 B)	2	1	-1	2	-	1	-1	2	-	1	-1
Oil Tank Truck (226 B)	1196	1124	-72	1178	-18	1148	-48	1172	-24	993	-203
Refined Products Bulk Sta. (69 MBD)	5	4	-1	5	-	4	-1	5	-	3	-2
COAL											
Underground Coal Mine (300,000 tonnes/yr)	7	7	-	7	-	7	-	10	+3	9	+2
Coal Truck (22.7 tonnes)	35	35	-	35	-	35	-	41	+6	40	+5
SOLAR											
Solar Hot Water (1000 Dwellings)	-	-	-	84	+84	-	-	-	-	84	+84
ELECTRICITY											
Combustion Turbine Power Plant (15 MWE)	34	34	-	33	-1	22	-12	34	-	33	-1
Diesel Power Plant (5 MWE)	205	205	-	200	-5	132	-73	205	-	200	-5
Hydro Power Plant (25 MWE)	6	6	-	6	-	9	+3	6	-	9	+3
Hydro Power Plant (150 MWE)	35	36	+1	35	-	40	+5	35	-	40	+5
Geothermal Power (50 MWE)	-	-	-	1	+1	-	-	-	-	1	+1
200 KVAC Transmission Line	16	17	+1	16	-	21	+5	16	-	21	+5

RESOURCE REQUIREMENTS

Requirements for capital and labor to design and construct the energy-related facilities, as well as the annual costs and labor requirements for their operation and maintenance, were calculated based on the derived schedules using the model's extensive data base. The results for each category will be discussed in this section.

Capital

Reference Case: The cumulative capital requirements for Peru's energy industry are projected to be \$14.95 billion dollars for the 1977-2000 period. The breakdown of these expenditures by energy sector is given in Figure 4-1. As shown in this figure, capital requirements for electric power generation, transmission, and distribution dominate Peru's energy industry investment needs, with the construction of hydro plants the major component.

All dollar amounts are reported in January 1978 dollars and assume that no real escalation in construction costs will occur. This is based on the assumption that escalation of construction costs and general inflation occur at the same rate, i.e., 7% per annum. Capital costs were calculated according to the construction schedule assumed for each facility. For this assessment, the cost-of-money used in computing interest during construction for the import component of construction costs was assumed to be 8.5 percent. No interest during construction was assumed for the domestic component.

In computing debt service, a uniform 8.5 percent cost-of-money rate and 15 year repayment periods were used for the import component. For the domestic component, no cost-of-money was specified and repayment periods were set equal to the expected economic lifetimes of projects. As has been mentioned previously, the question of financing sources was not addressed. A summary of financial data for the import and domestic components of construction costs is given in Table 4-6. Analysis of these results is given in a separate financial analysis annex prepared by another organization (and not a part of this report).

BY ENERGY SECTION

BY ELECTRICITY SOURCE

Figure 4-1
PROJECTED SHARE
OF CUMULATIVE CAPITAL REQUIREMENTS
BY ENERGY SECTOR (1978-2000)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

FINANCIAL STATISTICS (MILLION DOLLARS, JAN 1978
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES+
PERU - REFERENCE CASE/IMPORTS

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000
C.D. TOTAL CAPITAL COSTS	261.	2468.	1012.	2468.	(2000)	13.0	11.4	9.3	10.3
C.D. BORROWINGS TO DATE	504.	23783.	1034.	23783.	(2000)	42.3	22.3	12.7	18.2
C.D. BORROWINGS IN GRACE	504.	4755.	207.	4755.	(2000)	8.3	11.6	10.2	10.2
C.D. INTEREST DURING CONSTRUCTION	29.	272.	100.	272.	(2000)	6.7	11.8	10.5	10.3
C.D. TOTAL DEBT TO DATE	504.	15495.	674.	15495.	(2000)	40.2	20.0	10.5	16.1
C.D. DEBT SERVICE - INTEREST	0.	994.	413.	994.	(2000)	9999.0	26.1	10.9	9999.0
C.D. DEBT SERVICE - PRINCIPAL	0.	952.	360.	952.	(2000)	9999.0	33.5	14.0	9999.0
C.D. TOTAL DEBT SERVICE	0.	1946.	773.	1946.	(2000)	9999.0	28.6	12.2	9999.0
R.D. TOTAL CAPITAL COSTS	279.	557.	405.	562.	(1999)	5.6	4.1	2.2	3.0
R.D. BORROWINGS TO DATE	539.	9858.	429.	9858.	(2000)	38.1	17.6	7.8	13.5
R.D. BORROWINGS IN GRACE	539.	1073.	47.	1073.	(2000)	1.2	4.3	3.0	3.0
R.D. INTEREST DURING CONSTRUCTION	31.	61.	39.	61.	(2000)	-0.3	4.4	3.3	3.0
R.D. TOTAL DEBT TO DATE	539.	3498.	152.	3498.	(2000)	31.0	12.2	3.3	8.5
R.D. DEBT SERVICE - INTEREST	0.	224.	155.	224.	(2000)	9999.0	17.8	3.6	9999.0
R.D. DEBT SERVICE - PRINCIPAL	0.	215.	127.	215.	(2000)	9999.0	24.7	6.5	9999.0
R.D. TOTAL DEBT SERVICE	0.	439.	283.	439.	(2000)	9999.0	20.2	4.9	9999.0

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH
+ INCLUDES REQUIREMENTS FOR ENERGY SUPPLY AND TRANSPORTATION FACILITIES

Table 4-6

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

REAL DOLLAR TOTAL DEBT TO DATE (MILLION DOLLARS, JAN 1974)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)				
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000	
OIL										
EXPLORATION, DEVELOPMENT, & PRODUCTION	171.	589.	26.	709.	(1988)	38.2	8.6	-1.0	5.5	
REFINING	145.	488.	21.	488.	(2000)	4.0	10.8	4.0	5.4	
PIPELINES	0.	2.	0.	14.	(1988)	0.0	0.0	9999.0	9999.0	
TANKERS, BARGES, TRUCKS	5.	88.	4.	92.	(1999)	46.1	6.1	9.5	12.9	
BULK STATIONS	0.	9.	0.	9.	(2000)	9999.0	14.1	8.2	9999.0	
OTHER	98.	89.	4.	113.	(1978)	3.7	-12.1	3.0	-0.4	
TOTAL OIL	419.	1266.	55.	1266.	(2000)	20.9	5.9	1.3	4.9	
GAS										
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	6.	0.	6.	(2000)	0.0	0.0	9999.0	9999.0	
PIPELINES	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
DISTRIBUTION	0.	14.	1.	14.	(2000)	9999.0	40.8	9.4	9999.0	
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
TOTAL GAS	0.	20.	1.	20.	(2000)	9999.0	40.8	12.1	9999.0	
COAL										
MINING	0.	49.	2.	49.	(2000)	0.0	0.0	9999.0	9999.0	
TRANSPORTATION	0.	1.	0.	1.	(2000)	9999.0	40.9	8.4	9999.0	
TOTAL COAL	0.	50.	2.	50.	(2000)	9999.0	40.9	39.7	9999.0	
ELECTRIC UTILITIES										
CONVENTIONAL HYDRO	116.	1697.	74.	1697.	(2000)	49.0	11.5	6.5	12.4	
MINI & MICRO HYDRO	0.	4.	0.	4.	(2000)	45.4	9.4	3.6	9.6	
COMBUSTION TURBINE	0.	29.	1.	66.	(1990)	9999.0	42.0	-4.1	9999.0	
DIESEL	0.	96.	4.	227.	(1990)	9999.0	48.9	-4.5	9999.0	
OTHER OIL & GAS FUELED	0.	11.	0.	16.	(1997)	0.0	0.0	9999.0	9999.0	
CONVENTIONAL COAL-FIRED	0.	94.	4.	270.	(1992)	0.0	0.0	9999.0	9999.0	
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
HEAT RECOVERY	0.	3.	0.	19.	(1988)	0.0	9999.0	1.6	9999.0	
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
OTHER GENERATION	0.	-0.	-0.	36.	(1985)	0.0	9999.0	-100.0	0.0	
TOTAL GENERATION	117.	1935.	84.	1935.	(2000)	53.5	17.6	4.9	13.0	
TRANSMISSION	0.	156.	7.	156.	(2000)	9999.0	28.7	1.1	9999.0	
DISTRIBUTION	3.	71.	3.	71.	(2000)	55.6	21.3	5.5	14.4	
TOTAL UTILITIES	120.	2161.	94.	2161.	(2000)	57.8	18.8	4.5	13.4	
OTHER TECHNOLOGIES										
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
TOTAL ENERGY INDUSTRY	539.	3498.	152.	3498.	(2000)	31.0	12.2	3.3	8.5	

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

Table 4-6 (Continued)

FINANCIAL STATISTICS (MILLION DOLLARS, JAN 1978)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES+
PERU - REFERENCE CASE/DOMESTIC

CATEGORY	ANNUAL REQUIREMENTS-----					AVERAGE GROWTH RATES (X/YEAR)				
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000	2000
C.D. TOTAL CAPITAL COSTS	134.	1390.	516.	1390.	(2000)	12.7	8.4	11.1	10.7	
C.D. BORROWINGS TO DATE	203.	12062.	524.	12062.	(2000)	49.4	22.2	13.3	19.4	
C.D. BORROWINGS IN GRACE	203.	2273.	99.	2273.	(2000)	12.8	9.4	11.3	11.1	
C.D. INTEREST DURING CONSTRUCTION	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
C.D. TOTAL DEBT TO DATE	203.	9514.	414.	9514.	(2000)	47.0	20.4	12.5	18.2	
C.D. DEBT SERVICE - INTEREST	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
C.D. DEBT SERVICE - PRINCIPAL	0.	279.	111.	279.	(2000)	9999.0	27.0	12.0	9999.0	
C.D. TOTAL DEBT SERVICE	0.	279.	111.	279.	(2000)	9999.0	27.0	12.0	9999.0	
R.D. TOTAL CAPITAL COSTS	144.	314.	203.	314.	(2000)	5.3	1.3	3.8	3.4	
R.D. BORROWINGS TO DATE	217.	4877.	212.	4877.	(2000)	44.6	17.7	8.3	14.5	
R.D. BORROWINGS IN GRACE	217.	513.	22.	513.	(2000)	5.4	2.2	4.0	3.8	
R.D. INTEREST DURING CONSTRUCTION	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
R.D. TOTAL DEBT TO DATE	217.	2147.	93.	2147.	(2000)	37.4	12.5	5.1	10.5	
R.D. DEBT SERVICE - INTEREST	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
R.D. DEBT SERVICE - PRINCIPAL	0.	63.	41.	63.	(2000)	9999.0	18.7	4.7	9999.0	
R.D. TOTAL DEBT SERVICE	0.	63.	41.	63.	(2000)	9999.0	18.7	4.7	9999.0	

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

+ INCLUDES REQUIREMENTS FOR ENERGY SUPPLY AND TRANSPORTATION FACILITIES

Table 4-6 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 241

REAL DOLLAR TOTAL DERT SERVICE (MILLION DOLLARS, JAN 1978)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/DOMESTIC

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK YEAR		1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	22.	19.	24. (1994)		9999.0	16.4	1.5	9999.0
REFINING	0.	8.	5.	8. (1999)		9999.0	11.4	6.4	9999.0
PIPELINES	0.	0.	0.	0. (1989)		0.0	0.0	9999.0	9999.0
TANKERS, BARGES, TRUCKS	0.	2.	1.	2. (2000)		9999.0	8.4	6.9	9999.0
BULK STATIONS	0.	0.	0.	0. (1997)		0.0	9999.0	6.8	9999.0
OTHER	0.	1.	1.	1. (1981)		9999.0	-0.7	0.7	9999.0
TOTAL OIL	0.	33.	26.	34. (1996)		9999.0	14.6	2.7	9999.0
GAS									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0. (1997)		0.0	0.0	9999.0	9999.0
PIPELINES	0.	0.	0.	0.		0.0	0.0	0.0	0.0
DISTRIBUTION	0.	0.	0.	0. (1998)		0.0	9999.0	8.3	9999.0
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL GAS	0.	0.	0.	0. (1998)		0.0	9999.0	10.5	9999.0
COAL									
MINING	0.	1.	0.	1. (1999)		0.0	0.0	9999.0	9999.0
TRANSPORTATION	0.	0.	0.	0. (2000)		9999.0	35.6	7.9	9999.0
TOTAL COAL	0.	1.	0.	1. (1999)		9999.0	35.6	36.0	9999.0
ELECTRIC UTILITIES									
CONVENTIONAL HYDRO	0.	14.	6.	14. (2000)		9999.0	22.9	9.5	9999.0
MINI & MICRO HYDRO	0.	2.	1.	2. (2000)		9999.0	15.7	5.8	9999.0
COMBUSTION TURBINE	0.	0.	0.	1. (1993)		9999.0	60.5	2.5	9999.0
DIESEL	0.	2.	2.	2. (1993)		9999.0	101.5	2.6	9999.0
OTHER OIL & GAS FUELED	0.	0.	0.	0. (1998)		0.0	0.0	9999.0	9999.0
CONVENTIONAL COAL-FIRED	0.	2.	1.	3. (1993)		0.0	0.0	9999.0	9999.0
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	0.	0.	0. (1989)		0.0	0.0	9999.0	9999.0
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER GENERATION	0.	0.	0.	0. (1986)		0.0	0.0	9999.0	9999.0
TOTAL GENERATION	0.	21.	11.	21. (2000)		9999.0	27.6	8.5	9999.0
TRANSMISSION	0.	3.	2.	3. (2000)		0.0	9999.0	3.2	9999.0
DISTRIBUTION	0.	4.	2.	4. (2000)		9999.0	34.9	8.9	9999.0
TOTAL UTILITIES	0.	28.	15.	28. (2000)		9999.0	34.2	7.8	9999.0
OTHER TECHNOLOGIES									
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	0.	63.	41.	63. (2000)		9999.0	18.7	4.7	9999.0
A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH									

Table 4-6 (Continued)

Annual capital expenditures are projected to increase from a level of 423 million dollars in 1977 to 871 million in 2000, an average annual growth rate of 3.2%. Table 4-7 shows the annual time-stream of direct construction capital requirements by energy industry sector for the domestic and import components. Total capital requirements may be obtained by summing these components. The period of maximum growth occurs in the initial 1977-80 period, with total capital expenditures increasing at a 5.4% average annual rate, resulting primarily from increased capital expenditures for the electric power sector. The electric power sector increases from 116 million dollars in 1977 to 520 million dollars in 2000, an annual rate of 6.8%. During the 1977-80 period, however, investment requirements for the construction of hydro plants increase at a 13.4% average annual rate, and requirements for the construction of electric transmission and distribution systems increase at an average annual rate of 29.8%.

Annual capital expenditures for the oil sector increase from 307 million dollars in 1977 to 327 million dollars in 2000, at an annual average rate of 0.3%. Capital requirements for the oil sector increase at a significantly lower rate than the projected increase in oil production (6.2% average annual rate). The reason for this is that most of the increased production capacity is projected to be provided by fields in the Amazon jungle, where it is assumed that output per well would be sufficiently high to offset the increased initial costs of exploration and development, resulting in relatively less capital per barrel of output than coastal oil recovery. This results in a lower rate of growth in total capital spending, 3.2%, than the assumed rate of growth of Peruvian energy production, 3.8%.

Direct foreign purchases of labor, materials and equipment have also been computed by the ESPM. The import component of total capital requirements represents the fraction of materials and equipment assumed to be imported for the construction of the facilities, as well as the use of expatriate labor (accounting for differential wage levels and productivity rates). Of the \$13.98 billion total cumulative capital requirements, \$7.2 billion (48%)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL									
EXPLORATION, DEVELOPMENT, & PRODUCTION	123.	102.	94.	123.	(1977)	-2.1	-3.0	0.2	-0.8
REFINING	37.	81.	50.	81.	(1998)	6.9	6.6	1.9	3.5
PIPELINES	0.	0.	1.	12.	(1988)	0.0	0.0	0.0	0.0
TANKERS, BARGES, TRUCKS	5.	8.	9.	53.	(1999)	-5.9	-0.9	4.6	2.0
BULK STATIONS	0.	3.	1.	3.	(1981)	9999.0	-100.0	9999.0	9999.0
OTHER	36.	14.	7.	36.	(1977)	-39.8	-100.0	9999.0	-4.0
TOTAL OIL	201.	209.	162.	245.	(1999)	-4.7	-1.1	1.6	0.2
GAS									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	2.	0.	2.	(2000)	0.0	0.0	9999.0	9999.0
PIPELINES	0.	0.	0.	0.		0.0	0.0	0.0	0.0
DISTRIBUTION	0.	3.	1.	3.	(2000)	9999.0	-14.4	18.7	9999.0
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL GAS	0.	5.	2.	5.	(2000)	9999.0	-14.4	23.8	9999.0
COAL									
MINING	0.	10.	4.	10.	(2000)	0.0	0.0	9999.0	9999.0
TRANSPORTATION	0.	0.	0.	0.	(1997)	0.0	9999.0	4.7	9999.0
TOTAL COAL	0.	10.	4.	10.	(2000)	0.0	9999.0	39.0	9999.0
ELECTRIC UTILITIES									
CONVENTIONAL HYDRO	76.	286.	163.	286.	(2000)	6.6	10.0	4.5	5.9
MINI & MICRO HYDRO	0.	1.	0.	1.	(1999)	-2.8	-0.5	2.6	1.2
COMBUSTION TURBINE	0.	5.	7.	14.	(1983)	9999.0	21.4	-6.9	9999.0
DIESEL	0.	3.	24.	49.	(1984)	9999.0	16.1	-16.8	9999.0
OTHER OIL & GAS FUELED	0.	0.	1.	5.	(1995)	0.0	0.0	0.0	0.0
CONVENTIONAL COAL-FIRED	0.	0.	13.	90.	(1990)	0.0	0.0	0.0	0.0
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	0.	1.	7.	(1987)	0.0	9999.0	-100.0	0.0
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER GENERATION	0.	0.	2.	13.	(1984)	0.0	9999.0	-100.0	0.0
TOTAL GENERATION	76.	293.	210.	296.	(1995)	15.4	13.1	2.0	6.0
TRANSMISSION	0.	28.	20.	44.	(1981)	9999.0	-16.1	4.9	9999.0
DISTRIBUTION	2.	11.	8.	11.	(1999)	29.3	8.8	3.4	7.6
TOTAL UTILITIES	78.	332.	238.	332.	(2000)	25.5	8.9	2.3	6.5
OTHER TECHNOLOGIES									
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	279.	557.	405.	562.	(1999)	5.6	4.1	2.2	3.0

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7

RECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

RESOURCES	1977	1978	1979	1980	1981	1982	1983
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	123.	122.	121.	115.	121.	108.	108.
REFINING	37.	0.	15.	45.	61.	37.	15.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	5.	5.	5.	4.	4.	3.	3.
BULK STATIONS	0.	0.	0.	2.	3.	0.	0.
OTHER	36.	23.	10.	8.	0.	0.	0.
TOTAL OIL	201.	150.	151.	174.	190.	147.	125.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	0.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	0.	0.	0.	1.	1.	1.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	0.	0.	0.	1.	1.	1.
COAL							
MINING	0.	0.	0.	0.	0.	0.	0.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	0.	0.	0.	0.	0.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	76.	116.	112.	92.	76.	74.	106.
MINI & MICRO HYDRO	0.	0.	0.	0.	0.	0.	0.
COMBUSTION TURBINE	0.	0.	5.	5.	9.	10.	14.
DIESEL	0.	1.	7.	20.	33.	43.	48.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	0.	4.	10.
TOTAL GENERATION	76.	117.	124.	117.	118.	130.	178.
TRANSMISSION	0.	0.	5.	33.	44.	23.	39.
DISTRIBUTION	2.	3.	3.	4.	5.	6.	6.
TOTAL UTILITIES	78.	120.	132.	154.	168.	159.	223.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY

279.

270.

283.

329.

359.

307.

349.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

RESOURCES	1984	1985	1986	1987	1988	1989	1990
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	99.	99.	92.	93.	94.	92.	83.
REFINING	45.	61.	51.	45.	61.	51.	45.
PIPELINES	0.	0.	0.	2.	12.	0.	0.
TANKERS, BARGES, TRUCKS	3.	4.	50.	5.	5.	5.	5.
BULK STATIONS	0.	0.	2.	3.	0.	0.	0.
OTHER	0.	0.	0.	0.	2.	4.	6.
TOTAL OIL	147.	165.	195.	147.	174.	152.	138.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	1.	2.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	0.	0.	1.	2.	2.	1.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	0.	0.	1.	3.	4.	1.
COAL							
MINING	0.	0.	3.	5.	2.	3.	5.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	3.	6.	2.	3.	6.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	109.	148.	142.	147.	177.	152.	87.
MINI & MICRO HYDRO	0.	0.	0.	0.	0.	0.	0.
COMBUSTION TURBINE	14.	13.	9.	9.	9.	9.	9.
DIESEL	49.	42.	36.	32.	31.	29.	29.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	4.	24.	65.	90.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	2.	5.	7.	6.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	13.	12.	0.	0.	0.	0.	0.
TOTAL GENERATION	186.	217.	193.	199.	248.	255.	214.
TRANSMISSION	20.	14.	20.	12.	20.	9.	14.
DISTRIBUTION	6.	7.	7.	7.	7.	8.	8.
TOTAL UTILITIES	213.	237.	219.	219.	275.	271.	236.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY

360.

402.

417.

473.

453.

430.

380.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

RESOURCES	1991	1992	1993	1994	1995	1996	1997
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	82.	76.	82.	78.	76.	70.	72.
REFINING	61.	51.	45.	61.	51.	45.	76.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	5.	5.	5.	6.	6.	6.	7.
BULK STATIONS	2.	3.	0.	0.	2.	3.	0.
OTHER	0.	2.	4.	7.	4.	12.	17.
TOTAL OIL	150.	137.	136.	152.	139.	136.	173.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	1.	2.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	2.	2.	1.	2.	3.	2.	2.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	2.	2.	1.	2.	4.	4.	2.
COAL							
MINING	5.	5.	5.	5.	5.	9.	7.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	5.	6.	5.	6.	5.	9.	7.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	44.	119.	213.	255.	270.	244.	257.
MINI & MICRO HYDRO	0.	0.	0.	0.	1.	1.	1.
COMBUSTION TURBINE	5.	9.	5.	5.	5.	4.	0.
DIESEL	24.	23.	18.	18.	16.	13.	13.
OTHER OIL & GAS FUELED	0.	0.	1.	3.	5.	5.	4.
CONVENTIONAL COAL-FIRED	79.	47.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	0.	0.	0.
TOTAL GENERATION	152.	198.	238.	281.	296.	267.	275.
TRANSMISSION	13.	29.	18.	16.	26.	20.	12.
DISTRIBUTION	8.	9.	9.	9.	10.	10.	10.
TOTAL UTILITIES	173.	236.	265.	306.	332.	296.	297.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY 330. 381. 407. 466. 479. 445. 479.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7, (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

RESOURCES	1998	1999	2000	TOTAL 1978-2000
OIL				
EXPLORATION, DEVELOPMENT, & PRODUCTION	77.	91.	102.	2151.
REFINING	81.	76.	81.	1161.
PIPELINES	0.	0.	0.	14.
TANKERS, BARGES, TRUCKS	7.	53.	8.	208.
BULK STATIONS	0.	2.	3.	23.
OTHER	24.	24.	14.	160.
TOTAL OIL	189.	245.	209.	3719.
GAS				
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	1.	2.	11.
PIPELINES	0.	0.	0.	0.
DISTRIBUTION	1.	2.	3.	30.
OTHER	0.	0.	0.	0.
TOTAL GAS	1.	3.	5.	40.
COAL				
MINING	5.	9.	10.	83.
TRANSPORTATION	0.	0.	0.	3.
TOTAL COAL	5.	9.	10.	86.
ELECTRIC UTILITIES				
CONVENTIONAL HYDRO	253.	259.	286.	3738.
MINI & MICRO HYDRO	1.	1.	1.	10.
COMBUSTION TURBINE	4.	0.	5.	156.
DIESEL	8.	7.	3.	541.
OTHER OIL & GAS FUELED	0.	0.	0.	17.
CONVENTIONAL COAL-FIRED	0.	0.	0.	308.
SULFUR REMOVAL	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	20.
GEOTHERMAL	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	39.
TOTAL GENERATION	265.	267.	293.	4829.
TRANSMISSION	29.	27.	28.	471.
DISTRIBUTION	10.	11.	11.	173.
TOTAL UTILITIES	305.	305.	332.	5474.
OTHER TECHNOLOGIES				
SOLAR WATER HEATING	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	500.	562.	557.	9319.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/DOMESTIC

CATEGORY	ANNUAL REQUIREMENTS				AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL								
EXPLORATION, DEVELOPMENT, & PRODUCTION	59.	65.	46.	65. (2000)	-3.7	-4.4	2.9	0.4
REFINING	28.	39.	18.	39. (1998)	-27.7	6.4	6.8	1.4
PIPELINES	0.	0.	0.	5. (1988)	0.0	0.0	0.0	0.0
TANKERS, BARGES, TRUCKS	2.	3.	3.	18. (1999)	-5.9	-0.9	4.6	2.0
BULK STATIONS	0.	3.	1.	3. (1981)	9999.0	-100.0	9999.0	9999.0
OTHER	17.	7.	3.	17. (1977)	-28.9	-100.0	9999.0	-3.5
TOTAL OIL	106.	118.	71.	118. (2000)	-12.0	-4.2	4.8	0.5
GAS								
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	1.	0.	1. (1996)	0.0	0.0	9999.0	9999.0
PIPELINES	0.	0.	0.	0.	0.0	0.0	0.0	0.0
DISTRIBUTION	0.	2.	1.	2. (2000)	9999.0	-15.7	21.9	9999.0
OTHER	0.	0.	0.	0.	0.0	0.0	0.0	0.0
TOTAL GAS	0.	3.	1.	3. (2000)	9999.0	-15.7	25.0	9999.0
COAL								
MINING	0.	5.	2.	5. (2000)	0.0	0.0	9999.0	9999.0
TRANSPORTATION	0.	0.	0.	0. (1997)	0.0	9999.0	4.7	9999.0
TOTAL COAL	0.	5.	2.	5. (2000)	0.0	9999.0	46.0	9999.0
ELECTRIC UTILITIES								
CONVENTIONAL HYDRO	29.	135.	77.	140. (1995)	22.9	5.2	4.5	6.9
MINI & MICRO HYDRO	4.	5.	4.	6. (1999)	-2.8	-0.5	2.7	1.3
COMBUSTION TURBINE	0.	1.	2.	4. (1983)	9999.0	22.3	-6.9	9999.0
DIESEL	0.	1.	8.	16. (1984)	9999.0	16.5	-16.8	9999.0
OTHER OIL & GAS FUELED	0.	0.	0.	3. (1997)	0.0	0.0	0.0	0.0
CONVENTIONAL COAL-FIRED	0.	0.	5.	31. (1991)	0.0	0.0	0.0	0.0
SULFUR REMOVAL	0.	0.	0.	0.	0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	0.	0.	4. (1988)	0.0	9999.0	-100.0	0.0
GEOTHERMAL	0.	0.	0.	0.	0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.	0.0	0.0	0.0	0.0
OTHER GENERATION	0.	0.	1.	6. (1985)	0.0	9999.0	-100.0	0.0
TOTAL GENERATION	33.	143.	97.	150. (1995)	25.5	8.2	2.6	6.6
TRANSMISSION	0.	19.	14.	33. (1981)	9999.0	-17.1	6.2	9999.0
DISTRIBUTION	5.	26.	18.	26. (1999)	29.7	9.2	3.4	7.8
TOTAL UTILITIES	38.	188.	129.	194. (1995)	36.1	4.9	3.0	7.2
OTHER TECHNOLOGIES								
SOLAR WATER HEATING	0.	0.	0.	0.	0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.	0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	144.	314.	203.	314. (2000)	5.3	1.3	3.8	3.4

* A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 241

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/DOMESTIC

RESOURCES	1977	1978	1979	1980	1981	1982	1983
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	59.	59.	59.	53.	55.	44.	44.
REFINING	28.	0.	3.	11.	15.	28.	3.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	2.	2.	2.	1.	1.	1.	1.
BULK STATIONS	0.	0.	0.	1.	3.	0.	0.
OTHER	17.	11.	2.	6.	0.	0.	0.
TOTAL OIL	106.	72.	66.	72.	74.	73.	47.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	0.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	0.	0.	0.	1.	1.	1.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	0.	0.	0.	1.	1.	1.
COAL							
MINING	0.	0.	0.	0.	0.	0.	0.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	0.	0.	0.	0.	0.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	29.	53.	53.	54.	37.	28.	59.
MINI & MICRO HYDRO	4.	4.	4.	4.	3.	3.	3.
COMBUSTION TURBINE	0.	0.	1.	1.	2.	2.	4.
DIESEL	0.	0.	2.	6.	11.	14.	16.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	0.	1.	2.
TOTAL GENERATION	33.	57.	61.	66.	54.	49.	84.
TRANSMISSION	0.	0.	2.	20.	33.	14.	27.
DISTRIBUTION	5.	6.	8.	10.	12.	13.	15.
TOTAL UTILITIES	38.	64.	71.	95.	99.	76.	126.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY 144. 135. 137. 168. 173. 150. 175.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/DOMESTIC

RESOURCES	1984	1985	1986	1987	1988	1989	1990
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	38.	42.	39.	38.	41.	43.	39.
REFINING	11.	15.	31.	11.	15.	31.	11.
PIPELINES	0.	0.	0.	1.	5.	0.	0.
TANKERS, BARGES, TRUCKS	1.	1.	17.	1.	2.	2.	2.
BULK STATIONS	0.	0.	1.	3.	0.	0.	0.
OTHER	0.	0.	0.	0.	1.	1.	3.
TOTAL OIL	50.	58.	68.	55.	62.	77.	54.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	1.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	0.	0.	1.	1.	2.	1.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	0.	0.	1.	1.	3.	1.
COAL							
MINING	0.	0.	1.	1.	3.	1.	1.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	1.	1.	3.	1.	1.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	43.	70.	73.	69.	76.	74.	59.
MINI & MICRO HYDRO	3.	4.	4.	4.	4.	4.	4.
COMBUSTION TURBINE	4.	4.	2.	2.	2.	2.	2.
DIESEL	16.	14.	12.	10.	10.	10.	9.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	1.	8.	20.	27.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	1.	2.	2.	4.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	3.	6.	0.	0.	0.	0.	0.
TOTAL GENERATION	70.	98.	93.	89.	104.	110.	102.
TRANSMISSION	15.	8.	14.	7.	14.	5.	10.
DISTRIBUTION	15.	16.	16.	17.	18.	18.	19.
TOTAL UTILITIES	100.	121.	123.	113.	136.	134.	132.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY 150. 179. 213. 170. 202. 214. 188.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 241

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
 FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
 PERU - REFERENCE CASE/DOMESTIC

RESOURCES	1991	1992	1993	1994	1995	1996	1997
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	40.	37.	43.	42.	45.	43.	46.
REFINING	15.	31.	11.	15.	31.	11.	18.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	2.	2.	2.	2.	2.	2.	2.
BULK STATIONS	1.	3.	0.	0.	1.	3.	0.
OTHER	0.	1.	1.	3.	1.	4.	4.
TOTAL OIL	57.	74.	56.	62.	81.	63.	70.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	1.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	1.	2.	1.	1.	2.	1.	2.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	1.	2.	1.	1.	2.	2.	2.
COAL							
MINING	4.	1.	4.	1.	4.	2.	4.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	4.	1.	4.	1.	4.	2.	4.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	18.	46.	91.	117.	140.	110.	124.
MINI & MICRO HYDRO	5.	5.	5.	5.	5.	5.	5.
COMBUSTION TURBINE	1.	2.	1.	1.	1.	1.	0.
DIESEL	8.	8.	6.	6.	5.	4.	4.
OTHER OIL & GAS FUELED	0.	0.	0.	1.	2.	1.	3.
CONVENTIONAL COAL-FIRED	31.	30.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	0.	0.	0.
TOTAL GENERATION	63.	91.	104.	130.	154.	122.	137.
TRANSMISSION	7.	20.	13.	10.	17.	14.	7.
DISTRIBUTION	20.	21.	22.	22.	23.	24.	24.
TOTAL UTILITIES	90.	132.	138.	162.	194.	160.	168.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	152.	209.	198.	226.	280.	228.	244.

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

TOTAL CAPITAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE/DOMESTIC

RESOURCES	1998	1999	2000	TOTAL 1978-2000
OIL				
EXPLORATION, DEVELOPMENT, & PRODUCTION	48.	58.	65.	1060.
REFINING	39.	18.	39.	411.
PIPELINES	0.	0.	0.	6.
TANKERS, BARGES, TRUCKS	2.	18.	3.	69.
BULK STATIONS	0.	1.	3.	24.
OTHER	5.	11.	7.	62.
TOTAL OIL	95.	106.	118.	1632.
GAS				
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	1.	4.
PIPELINES	0.	0.	0.	0.
DISTRIBUTION	1.	1.	2.	20.
OTHER	0.	0.	0.	0.
TOTAL GAS	1.	1.	3.	24.
COAL				
MINING	4.	2.	5.	36.
TRANSPORTATION	0.	0.	0.	1.
TOTAL COAL	4.	2.	5.	37.
ELECTRIC UTILITIES				
CONVENTIONAL HYDRO	123.	117.	135.	1775.
MINI & MICRO HYDRO	6.	6.	5.	101.
COMBUSTION TURBINE	1.	0.	1.	41.
DIESEL	3.	2.	1.	179.
OTHER OIL & GAS FUELED	0.	0.	0.	7.
CONVENTIONAL COAL-FIRED	0.	0.	0.	117.
SULFUR REMOVAL	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	8.
GEOTHERMAL	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	13.
TOTAL GENERATION	133.	125.	143.	2239.
TRANSMISSION	19.	18.	19.	311.
DISTRIBUTION	25.	26.	26.	417.
TOTAL UTILITIES	177.	169.	188.	2967.
OTHER TECHNOLOGIES				
SOLAR WATER HEATING	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.

TOTAL ENERGY INDUSTRY 277. 278. 314. 4660.
* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-7 (Continued)

represents foreign materials, equipment, and labor. The import component constitutes 89% of the equipment, 53% of the materials and 38% of the labor costs. Approximately 26% of the manual labor costs are for expatriate labor as are 69% of the technical labor costs.

Alternative Energy Strategies: The impact of the alternative energy strategies on capital requirements is given in Table 4-8. As shown in this table, lower capital expenditures are required for all alternative strategies with the exception of the Increased Hydro Case and the Reduced Petroleum Case. Lower capital expenditures result primarily from reduced oil consumption, which is assumed to occur in all cases. This reduction in capital expenditure is related to lower requirements for refineries and transportation facilities. The savings in foreign exchange which would accrue from a corresponding reduction in crude oil imports are not included in the calculations. In the Increased Hydro and Reduced Petroleum Cases, increased capital requirements for hydro plants offset the reduction of capital requirements for the oil sector. The lowest requirements for energy-related capital occur in the Increased Energy Efficiency Case, which reduces oil consumption through improved energy utilization and conservation by end-use devices without increasing production from alternative sources, and in the Increased Coal Case, which substitutes increased coal production for oil. The capital requirements for the Increased Efficiency Case are understated somewhat because they do not include capital costs related to increased conservation and more efficient utilization of end-use devices. It is interesting to note that the substitution of coal for oil in the Increased Coal Case results in a net saving of \$227 million dollars. The reduction in foreign exchange from reduced crude oil imports is not calculated and would result in further savings.

The total costs for the Increased Renewables and Increased Hydro Cases are understated as they include neither the capital costs for the construction of solar electric, wind, and wood gasification power plants nor the costs of the use of charcoal, biogas and gasohol. Based on U.S. estimates of \$1000-2000 per kWe, less than four million dollars would be required for

Table 4-8

IMPACT OF ALTERNATIVE ENERGY STRATEGIES
ON CUMULATIVE INVESTMENT REQUIREMENTS: 1978-2000
(in million January 1978 dollars)

Energy Sector	Reference Case	Increased Energy Efficiency		Increased Renewables		Increased Hydro		Increased Coal		Reduced Petroleum	
		Cost	Change	Cost	Change	Cost	Change	Cost	Change	Cost	Change
Oil	5351	4909	-442	5079	-272	4936	-415	5078	-273	4149	-1202
Gas	64	64	-	64	-	64	-	64	-	64	-
Coal	123	123	-	123	-	123	-	169	+46	154	+31
Electric Utilities	8441	8618	+177	8464	+23	9201	+760	8441	-	9551	+1110
• Hydro	5623	5764	+141	5623	-	6525	+902	5623	-	6525	+902
• Geothermal	-	-	-	47	+47	-	-	-	-	47	+47
• Other Generation	1445	1444	-	1421	-24	1117	-328	1445	-	1421	-21
• Transmission & Distribution	1373	1410	+37	1373	-	1559	+186	1373	-	1559	+186
Solar	-	-	-	85	+85	-	-	-	-	85	+85
TOTAL	13978	13714	-264	13814	-164	14325	+347	13752	-226	14002	+24

solar and wind power facilities included in these strategies. Due to the relatively small additional capital requirements, the overall results would not be significantly altered for these two strategies.

In conclusion, it may be stated that the capital costs related to each of the strategies vary by less than 2.5% from the Reference Case. Thus, total capital costs may not be the most sensitive criteria for selection between alternative strategies.

A final note concerning projected capital costs for the Reference Case and the five alternative strategies is that the costs presented here are those which are required to meet Peru's energy needs. Not included in these projections are those costs which would be required to develop Peru's potential for export. The question of whether or not Peru's petroleum production would be developed by Petroperu or the multinational oil companies was not addressed in this study.

Labor

Reference Case: Construction labor requirements in the Reference Case increase at an average annual rate of 3.9% during the 1977-2000 period, from a level of 7.5 thousand person-years in 1977 to 18.1 thousand in 2000. The annual time-stream of construction labor requirements by energy sector is presented in Table 4-9. Over 63% of the projected labor requirements in 2000 are associated with the electric power sector, which increases from 2.8 thousand person-years in 1977 to 11.6 thousand in 2000. Almost 43% of the total labor employed by the energy sectors in 2000 will be for the construction of hydroelectric plants. Requirements for manual labor, which constitute about 90% of the project construction labor force, increase at an average annual rate of 3.8% from 6.8 thousand person-years in 1977 to 16.0 thousand in 2000; while requirements for non-manual labor increase at a rate of 4.3% from 0.8 to 2.1 thousand person years in 2000.

TOTAL CONSTRUCTION LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK YEAR		1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL									
EXPLORATION, DEVELOPMENT, & PRODUCTION	2485.	2739.	2098.	2739. (2000)		-0.8	-3.4	2.0	-0.4
REFINING	1103.	3002.	1919.	3002. (1997)		19.9	8.1	0.4	4.4
PIPELINES	0.	0.	19.	319. (1988)		0.0	0.0	0.0	0.0
TANKERS, BARGES, TRUCKS	0.	0.	0.	0.		0.0	0.0	0.0	0.0
BULK STATIONS	0.	92.	34.	92. (1981)		9999.0	-100.0	9999.0	9999.0
OTHER	1143.	356.	258.	1143. (1977)		-44.7	-100.0	9999.0	-4.9
TOTAL OIL	4731.	6189.	4327.	6295. (1999)		-1.0	1.1	1.6	1.2
GAS									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	73.	14.	73. (1989)		0.0	0.0	9999.0	9999.0
PIPELINES	0.	0.	0.	0.		0.0	0.0	0.0	0.0
DISTRIBUTION	0.	122.	63.	122. (2000)		9999.0	-41.7	30.1	9999.0
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL GAS	0.	195.	77.	195. (2000)		9999.0	-41.7	34.3	9999.0
COAL									
MINING	0.	117.	42.	117. (2000)		0.0	0.0	9999.0	9999.0
TRANSPORTATION	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL COAL	0.	117.	42.	117. (2000)		0.0	0.0	9999.0	9999.0
ELECTRIC UTILITIES									
CONVENTIONAL HYDRO	2376.	9048.	5217.	9048. (2000)		10.1	8.8	4.3	6.0
WIND & MICRO HYDRO	214.	307.	234.	308. (1999)		-2.8	-0.7	3.2	1.6
COMBUSTION TURBINE	0.	48.	72.	145. (1983)		9999.0	22.7	-6.9	9999.0
DIESEL	0.	33.	292.	613. (1984)		9999.0	16.2	-16.8	9999.0
OTHER OIL & GAS FUELED	0.	0.	33.	266. (1995)		0.0	0.0	0.0	0.0
CONVENTIONAL COAL-FIRED	0.	0.	227.	1799. (1990)		0.0	0.0	0.0	0.0
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	0.	38.	332. (1987)		0.0	9999.0	-100.0	0.0
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER GENERATION	0.	0.	42.	361. (1984)		0.0	9999.0	-100.0	0.0
TOTAL GENERATION	2590.	9436.	6155.	9525. (1995)		12.3	10.5	3.0	5.8
TRANSMISSION	0.	768.	539.	1350. (1981)		9999.0	-17.2	7.0	9999.0
DISTRIBUTION	228.	1384.	956.	1364. (1990)		31.5	9.9	3.5	8.2
TOTAL UTILITIES	2817.	11588.	7650.	11588. (2000)		20.2	7.8	3.3	6.3
OTHER TECHNOLOGIES									
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	7549.	18089.	12096.	18089. (2000)		8.0	4.7	2.8	3.9
A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH									

Table 4-9

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL CONSTRUCTION LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1977	1978	1979	1980	1981	1982	1983
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	2485.	2504.	2500.	2429.	2448.	2113.	2117.
REFINING	1103.	0.	196.	1899.	2807.	1103.	196.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	0.	0.	0.	0.	0.	0.	0.
BULK STATIONS	0.	0.	0.	65.	92.	0.	0.
OTHER	1143.	739.	342.	194.	0.	0.	0.
TOTAL OIL	4731.	3242.	3037.	4586.	5347.	3216.	2313.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	0.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	0.	2.	35.	66.	65.	53.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	0.	2.	35.	66.	65.	53.
COAL							
MINING	0.	0.	0.	0.	0.	0.	0.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	0.	0.	0.	0.	0.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	2376.	3531.	3720.	3172.	2464.	2418.	3498.
MINI & MICRO HYDRO	214.	207.	204.	197.	184.	175.	172.
COMBUSTION TURBINE	0.	3.	48.	51.	97.	99.	145.
DIESEL	0.	6.	80.	244.	405.	530.	592.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	3.	70.	251.
TOTAL GENERATION	2590.	3747.	4052.	3664.	3152.	3292.	4658.
TRANSMISSION	0.	0.	88.	710.	1350.	505.	1086.
DISTRIBUTION	228.	317.	409.	518.	627.	697.	761.
TOTAL UTILITIES	2817.	4064.	4550.	4892.	5129.	4493.	6506.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	7549.	7306.	7589.	9513.	10543.	7774.	8872.

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Table 4-9 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL CONSTRUCTION LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1984	1985	1986	1987	1988	1989	1990
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	1965.	2040.	1921.	1909.	1942.	2049.	1886.
REFINING	1899.	2807.	1299.	1899.	2807.	1299.	1899.
PIPELINES	0.	0.	0.	110.	319.	0.	0.
TANKERS, BARGES, TRUCKS	0.	0.	0.	0.	0.	0.	0.
BULK STATIONS	0.	0.	65.	92.	0.	0.	0.
OTHER	0.	0.	0.	0.	127.	251.	246.
TOTAL OIL	3865.	4847.	3284.	4010.	5195.	3598.	4031.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	34.	73.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	0.	2.	35.	66.	67.	88.	66.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	0.	2.	35.	66.	102.	161.	66.
COAL							
MINING	0.	0.	48.	57.	12.	48.	57.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	0.	0.	48.	57.	12.	48.	57.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	3453.	4830.	4716.	4706.	5340.	4798.	2952.
MINI & MICRO HYDRO	180.	190.	204.	212.	219.	229.	234.
COMBUSTION TURBINE	145.	142.	97.	97.	97.	97.	94.
DIESEL	613.	518.	452.	393.	390.	360.	354.
OTHER OIL & GAS FUELED	0.	0.	0.	0.	0.	0.	0.
CONVENTIONAL COAL-FIRED	0.	0.	0.	13.	302.	1157.	1799.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	1.	59.	225.	332.	268.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	361.	288.	0.	0.	0.	0.	0.
TOTAL GENERATION	4753.	6027.	5695.	5752.	6616.	6640.	5433.
TRANSMISSION	622.	277.	605.	234.	605.	163.	426.
DISTRIBUTION	823.	831.	850.	915.	940.	962.	1007.
TOTAL UTILITIES	6199.	7134.	7150.	6901.	8161.	7765.	6865.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	10063.	11983.	10517.	11035.	13470.	11572.	11021.

Table 4-9 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL CONSTRUCTION LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1991	1992	1993	1994	1995	1996	1997
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	1827.	1791.	1947.	1898.	1918.	1881.	1935.
REFINING	2807.	1299.	1899.	2807.	1299.	1899.	3002.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
TANKERS, BARGES, TRUCKS	0.	0.	0.	0.	0.	0.	0.
BULK STATIONS	65.	92.	0.	0.	65.	92.	0.
OTHER	0.	127.	251.	373.	251.	408.	588.
TOTAL OIL	4698.	3309.	4097.	5078.	3532.	4281.	5525.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	34.	73.	0.
PIPELINES	0.	0.	0.	0.	0.	0.	0.
DISTRIBUTION	67.	88.	69.	100.	120.	67.	88.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	67.	88.	69.	100.	154.	141.	88.
COAL							
MINING	60.	57.	60.	57.	60.	105.	69.
TRANSPORTATION	0.	0.	0.	0.	0.	0.	0.
TOTAL COAL	60.	57.	60.	57.	60.	105.	69.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	1594.	3798.	6628.	8290.	8744.	7829.	8227.
MINI & MICRO HYDRO	244.	249.	259.	268.	273.	283.	288.
COMBUSTION TURBINE	51.	94.	48.	48.	48.	46.	3.
DIESEL	295.	289.	229.	226.	193.	164.	158.
OTHER OIL & GAS FUELED	0.	0.	5.	120.	266.	259.	112.
CONVENTIONAL COAL-FIRED	1433.	512.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	0.	0.	0.	0.
TOTAL GENERATION	3617.	4941.	7169.	8953.	9525.	8580.	8788.
TRANSMISSION	251.	811.	515.	385.	660.	605.	234.
DISTRIBUTION	1051.	1096.	1141.	1185.	1227.	1252.	1277.
TOTAL UTILITIES	4919.	6848.	8825.	10523.	11412.	10438.	10299.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	9745.	10303.	13050.	15758.	15158.	14964.	15981.

Table 4-9 (Continued)

TOTAL CONSTRUCTION LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE DESIGN, CONSTRUCTION, AND STARTUP OF ENERGY RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1998	1999	2000	TOTAL 1978-2000
OIL				
EXPLORATION, DEVELOPMENT, & PRODUCTION	2059.	2446.	2739.	48262.
REFINING	3002.	3002.	3002.	44129.
PIPELINES	0.	0.	0.	430.
TANKERS, BARGES, TRUCKS	0.	0.	0.	0.
BULK STATIONS	0.	65.	92.	783.
OTHER	892.	782.	356.	5927.
TOTAL OIL	5953.	6295.	6189.	99531.
GAS				
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	34.	73.	321.
PIPELINES	0.	0.	0.	0.
DISTRIBUTION	69.	100.	122.	1439.
OTHER	0.	0.	0.	0.
TOTAL GAS	69.	134.	195.	1760.
COAL				
MINING	60.	105.	117.	971.
TRANSPORTATION	0.	0.	0.	0.
TOTAL COAL	60.	105.	117.	971.
ELECTRIC UTILITIES				
CONVENTIONAL HYDRO	8038.	8193.	9048.	119987.
MINI & MICRO HYDRO	298.	308.	307.	5383.
COMBUSTION TURBINE	46.	3.	48.	1646.
DIESEL	98.	92.	33.	6714.
OTHER OIL & GAS FUELED	0.	0.	0.	763.
CONVENTIONAL COAL-FIRED	0.	0.	0.	5215.
SULFUR REMOVAL	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	885.
GEOTHERMAL	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.
OTHER GENERATION	0.	0.	0.	974.
TOTAL GENERATION	8480.	8596.	9436.	141566.
TRANSMISSION	785.	703.	768.	12388.
DISTRIBUTION	1339.	1384.	1384.	21992.
TOTAL UTILITIES	10604.	10683.	11588.	175946.
OTHER TECHNOLOGIES				
SOLAR WATER HEATING	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	16685.	17217.	18089.	278206.

Table 4-9 (Continued)

Operations and Maintenance (O&M) labor requirements for the Reference Case increase at a 4.9% average annual rate, from a level of 9.6 thousand person-years in 1977 to 29.2 thousand in 2000. About 42% of the O&M labor requirements in the year 2000 are related to the electric power sector, 46% to oil and gas, and 12% to coal. Labor requirements for the coal mining sector account for the greatest increases during the forecast period, increasing from essentially none in 1977 to 3.5 thousand person-years in 2000. The annual time-stream of O&M labor requirements by energy sector is presented in Table 4-10.

Alternative Energy Strategies: The impact of alternative energy strategies on construction, O&M, and total labor requirements in the year 2000 is presented in Table 4-11. All alternate strategies result in reduced labor requirements. This is due primarily to the reduced labor demand related to the decrease in oil production, refining, and transportation facilities resulting from the decline in oil consumption assumed in each strategy, a decline not offset by increases in labor requirements for the electric power and coal sectors. The largest decrease occurs in the Increased Efficiency Case, where total energy-related labor requirements decline by 4.2 thousand person years (8.8%); the smallest decline occurs in the Increased Renewables Strategy, where labor requirements decline by 1.8 thousand person-years (3.8%).

Operation and Maintenance Costs

Costs for Operation and Maintenance of energy-related facilities increase at a 4.8 percent average annual rate from an annual level of 117 million dollars in 1977, to 346 million dollars in 2000. Approximately, 56.2% of the costs are for the oil and gas sectors, 14.7% for the coal sector and 28.9% for the electric utilities sector (with 7.8% for the operation and maintenance of hydro plants). These costs include labor, materials, and equipment costs related to the Operation and Maintenance of energy-related facilities. They exclude carrying charges (e.g. interest costs

RECHTEL ENERGY SUPPLY PLANNING MODEL

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TOTAL LABOR REQUIREMENTS (PERSON-YEARS) FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES PERU - REFERENCE CASE

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL									
EXPLORATION, DEVELOPMENT, & PRODUCTION	1789.	4474.	3487.	4474.	(2000)	12.5	4.2	2.4	4.1
REFINING	1590.	3861.	2381.	3861.	(2000)	-3.0	3.1	5.7	3.9
PIPELINES	20.	45.	36.	51.	(1988)	-0.8	-1.2	6.1	3.6
TANKERS, BARGES, TRUCKS	1369.	3277.	2004.	3277.	(2000)	10.4	-3.9	5.3	3.9
BULK STATIONS	39.	124.	75.	124.	(2000)	-1.7	8.6	5.5	5.2
OTHER	486.	999.	721.	999.	(2000)	10.5	0.0	2.9	3.2
TOTAL OIL	5293.	12780.	8705.	12780.	(2000)	7.4	1.5	4.0	3.9
GAS									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	28.	7.	28.	(2000)	0.0	0.0	9999.0	9999.0
PIPELINES	6.	2.	4.	6.	(1977)	-2.6	-2.9	-4.3	-3.8
DISTRIBUTION	267.	501.	327.	501.	(2000)	-2.6	2.4	4.0	2.8
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL GAS	273.	531.	338.	531.	(2000)	-2.6	2.3	4.3	2.9
COAL									
MINING	0.	3430.	959.	3430.	(2000)	0.0	0.0	9999.0	9999.0
TRANSPORTATION	12.	108.	51.	108.	(2000)	2.4	19.1	8.8	10.1
TOTAL COAL	12.	3537.	1010.	3537.	(2000)	2.4	19.1	37.3	28.1
ELECTRIC UTILITIES									
CONVENTIONAL HYDRO	266.	1286.	691.	1286.	(2000)	12.6	4.8	6.8	7.1
MINI & MICRO HYDRO	0.	0.	0.	0.		0.0	0.0	0.0	0.0
COMBUSTION TURBINE	43.	114.	87.	114.	(2000)	1.8	11.1	2.7	4.4
DIESEL	2008.	5257.	4021.	5287.	(1999)	0.7	11.6	2.7	4.3
OTHER OIL & GAS FUELED	336.	285.	313.	336.	(1977)	0.0	-0.3	-1.0	-0.7
CONVENTIONAL COAL-FIRED	0.	269.	109.	269.	(1992)	0.0	0.0	9999.0	9999.0
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	38.	22.	38.	(1988)	0.0	0.0	9999.0	9999.0
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER GENERATION	190.	116.	194.	248.	(1985)	0.0	5.5	-4.9	-2.1
TOTAL GENERATION	2843.	7365.	5437.	7365.	(2000)	1.8	9.3	3.1	4.2
TRANSMISSION	83.	290.	188.	290.	(2000)	2.0	12.7	4.0	5.6
DISTRIBUTION	1118.	4699.	2625.	4699.	(2000)	4.5	8.0	6.3	6.4
TOTAL UTILITIES	4045.	12355.	8251.	12355.	(2000)	2.6	9.0	4.2	5.0
OTHER TECHNOLOGIES									
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	9622.	29203.	18303.	29203.	(2000)	5.1	4.7	5.0	4.9
A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH									

Table 4-10

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1977	1978	1979	1980	1981	1982	1983
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	1789.	2059.	2334.	2545.	2775.	2878.	2985.
REFINING	1590.	1543.	1497.	1450.	1404.	1831.	1784.
PIPELINES	20.	20.	20.	20.	20.	19.	19.
TANKERS, BARGES, TRUCKS	1369.	1583.	1743.	1844.	1861.	1794.	1686.
BULK STATIONS	39.	38.	37.	37.	59.	58.	57.
OTHER	486.	600.	600.	655.	655.	655.	655.
TOTAL OIL	5293.	5843.	6231.	6551.	6773.	7235.	7187.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	0.	0.
PIPELINES	6.	5.	5.	5.	5.	5.	5.
DISTRIBUTION	267.	260.	254.	247.	240.	233.	291.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	273.	266.	259.	252.	245.	238.	296.
COAL							
MINING	0.	0.	0.	0.	0.	0.	0.
TRANSPORTATION	12.	16.	14.	13.	17.	21.	25.
TOTAL COAL	12.	16.	14.	13.	17.	21.	25.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	266.	294.	322.	379.	388.	388.	445.
MINI & MICRO HYDRO	0.	0.	0.	0.	0.	0.	0.
COMBUSTION TURBINE	43.	42.	43.	45.	50.	54.	62.
DIESEL	2008.	1957.	1949.	2048.	2256.	2551.	2889.
OTHER OIL & GAS FUELED	336.	336.	336.	336.	336.	336.	336.
CONVENTIONAL COAL-FIRED	0.	0.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	0.	0.	0.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	190.	190.	190.	190.	190.	188.	186.
TOTAL GENERATION	2843.	2819.	2841.	2999.	3221.	3519.	3918.
TRANSMISSION	83.	83.	83.	88.	120.	124.	145.
DISTRIBUTION	1118.	1155.	1207.	1276.	1369.	1479.	1597.
TOTAL UTILITIES	4045.	4057.	4131.	4363.	4710.	5121.	5659.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	9622.	10182.	10635.	11179.	11745.	12615.	13167.

Table 4-10 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1984	1985	1986	1987	1988	1989	1990
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	3030.	3131.	3219.	3307.	3396.	3522.	3630.
REFINING	1738.	1691.	2118.	2072.	2025.	2453.	2406.
PIPELINES	19.	19.	18.	18.	51.	50.	50.
TANKERS, BARGES, TRUCKS	1576.	1514.	1684.	1677.	1695.	1719.	1763.
BLK STATIONS	56.	56.	54.	77.	75.	74.	73.
OTHER	655.	655.	655.	655.	655.	655.	714.
TOTAL OIL	7074.	7066.	7749.	7805.	7898.	8473.	8636.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	0.	9.	9.
PIPELINES	5.	4.	4.	4.	4.	4.	4.
DISTRIBUTION	285.	278.	271.	264.	257.	315.	309.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	289.	282.	275.	268.	261.	329.	322.
COAL							
MINING	0.	0.	0.	0.	490.	490.	490.
TRANSPORTATION	28.	31.	33.	35.	42.	43.	50.
TOTAL COAL	28.	31.	33.	35.	532.	533.	540.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	445.	478.	535.	568.	596.	653.	738.
MINI & MICRO HYDRO	0.	0.	0.	0.	0.	0.	0.
COMBUSTION TURBINE	69.	77.	81.	86.	90.	95.	99.
DIESEL	3248.	3543.	3794.	4002.	4210.	4396.	4583.
OTHER OIL & GAS FUELED	334.	331.	328.	324.	320.	316.	311.
CONVENTIONAL COAL-FIRED	0.	0.	0.	0.	0.	0.	0.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	0.	0.	0.	0.	38.	38.	38.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	184.	248.	244.	240.	236.	231.	225.
TOTAL GENERATION	4280.	4676.	4982.	5220.	5491.	5729.	5994.
TRANSMISSION	159.	160.	175.	175.	189.	189.	199.
DISTRIBUTION	1731.	1872.	2006.	2155.	2313.	2470.	2635.
TOTAL UTILITIES	6170.	6709.	7163.	7550.	7993.	8387.	8828.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	13561.	14087.	15220.	15658.	16684.	17722.	18326.

Table 4-10 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1991	1992	1993	1994	1995	1996	1997
OIL							
EXPLORATION, DEVELOPMENT, & PRODUCTION	3732.	3809.	3937.	4048.	4196.	4339.	4307.
REFINING	2360.	2789.	2750.	2713.	3150.	3113.	3072.
PIPELINES	50.	49.	49.	48.	48.	47.	47.
TANKERS, BARGES, TRUCKS	1825.	1898.	1989.	2097.	2220.	2360.	2521.
BULK STATIONS	72.	93.	92.	90.	88.	109.	107.
OTHER	714.	714.	714.	772.	772.	830.	830.
TOTAL OIL	8752.	9352.	9531.	9768.	10474.	10799.	10884.
GAS							
EXPLORATION, DEVELOPMENT, & PRODUCTION	9.	9.	9.	9.	9.	19.	19.
PIPELINES	4.	3.	3.	3.	3.	3.	3.
DISTRIBUTION	302.	360.	353.	346.	405.	398.	456.
OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL GAS	315.	373.	366.	359.	417.	419.	478.
COAL							
MINING	980.	980.	1470.	1470.	1960.	1960.	2450.
TRANSPORTATION	56.	62.	67.	72.	77.	82.	92.
TOTAL COAL	1036.	1042.	1537.	1542.	2037.	2041.	2541.
ELECTRIC UTILITIES							
CONVENTIONAL HYDRO	738.	738.	766.	823.	936.	974.	1059.
MINI & MICRO HYDRO	0.	0.	0.	0.	0.	0.	0.
COMBUSTION TURBINE	101.	106.	108.	109.	111.	113.	112.
DIESEL	4726.	4869.	4969.	5069.	5147.	5204.	5261.
OTHER OIL & GAS FUELED	305.	299.	292.	285.	277.	269.	314.
CONVENTIONAL COAL-FIRED	90.	269.	269.	269.	269.	269.	269.
SULFUR REMOVAL	0.	0.	0.	0.	0.	0.	0.
HEAT RECOVERY	38.	38.	38.	38.	38.	38.	38.
GEOTHERMAL	0.	0.	0.	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.	0.	0.	0.
OTHER GENERATION	219.	212.	203.	192.	180.	168.	155.
TOTAL GENERATION	6217.	6531.	6645.	6786.	6960.	7035.	7207.
TRANSMISSION	198.	214.	224.	229.	239.	253.	253.
DISTRIBUTION	2808.	2989.	3178.	3375.	3580.	3793.	4005.
TOTAL UTILITIES	9224.	9734.	10047.	10390.	10778.	11081.	11465.
OTHER TECHNOLOGIES							
SOLAR WATER HEATING	0.	0.	0.	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	19326.	20501.	21481.	22059.	23706.	24341.	25368.

4-52

Table 4-10 (Continued)

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 239

TOTAL LABOR REQUIREMENTS (PERSON-YEARS)
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES
PERU - REFERENCE CASE

RESOURCES	1998	1999	2000	TOTAL 1978-2000
OIL				
EXPLORATION, DEVELOPMENT, & PRODUCTION	4266.	4294.	4474.	80212.
REFINING	3500.	3448.	3861.	54769.
PIPELINES	46.	46.	45.	818.
TANKERS, BARGES, TRUCKS	2695.	3067.	3277.	46087.
BULK STATIONS	105.	102.	124.	1734.
OTHER	830.	944.	999.	16585.
TOTAL OIL	11442.	11901.	12780.	200204.
GAS				
EXPLORATION, DEVELOPMENT, & PRODUCTION	19.	19.	28.	169.
PIPELINES	3.	2.	2.	89.
DISTRIBUTION	449.	442.	501.	7515.
OTHER	0.	0.	0.	0.
TOTAL GAS	471.	464.	531.	7773.
COAL				
MINING	2940.	2940.	3430.	22048.
TRANSPORTATION	95.	105.	108.	1183.
TOTAL COAL	3035.	3044.	3537.	23231.
ELECTRIC UTILITIES				
CONVENTIONAL HYDRO	1144.	1201.	1286.	15894.
MINI & MICRO HYDRO	0.	0.	0.	0.
COMBUSTION TURBINE	113.	112.	114.	1993.
DIESEL	5274.	5287.	5257.	92490.
OTHER OIL & GAS FUELED	304.	295.	285.	7207.
CONVENTIONAL COAL-FIRED	269.	269.	269.	2512.
SULFUR REMOVAL	0.	0.	0.	0.
HEAT RECOVERY	38.	38.	38.	500.
GEOTHERMAL	0.	0.	0.	0.
NUCLEAR	0.	0.	0.	0.
OTHER GENERATION	142.	129.	116.	4456.
TOTAL GENERATION	7285.	7331.	7365.	125051.
TRANSMISSION	267.	277.	290.	4333.
DISTRIBUTION	4226.	4463.	4699.	60379.
TOTAL UTILITIES	11778.	12071.	12355.	189763.
OTHER TECHNOLOGIES				
SOLAR WATER HEATING	0.	0.	0.	0.
OTHER RENEWABLE ENERGY	0.	0.	0.	0.
TOTAL OTHER	0.	0.	0.	0.
TOTAL ENERGY INDUSTRY	26726.	27480.	29203.	420971.

Table 4-10 (Continued)

Table 4-11

IMPACT OF ALTERNATIVE ENERGY STRATEGIES
ON LABOR REQUIREMENTS IN THE YEAR 2000.
(in thousand person-years)

	Total	Construction	Operations & Maintenance
Reference Case	47.3	18.1	29.2
Increased Energy Efficiency Strategy	43.1	15.0	28.1
Impact	-4.2	-3.1	-1.1
Increased Renewables Strategy	45.5	15.7	29.8
Impact	-1.8	-2.4	+6
Increased Hydro Strategy	44.4	16.3	28.1
Impact	-2.9	-1.8	-1.1
Increased Coal Strategy	45.4	15.3	30.1
Impact	-1.9	-2.8	+9
Reduced Petroleum Strategy	43.6	15.4	28.2
Impact	-3.7	-2.7	-1.0

and depreciation of capital equipment and fuel costs. A summary of annual costs for the domestic and import components is given in Table 4-12. Total costs are obtained by summing these components.

A comparison of Operation and Maintenance costs in the year 2000 for each of the strategies is given in Table 4-13. All strategies result in reduced O&M costs, which are related to lower requirements for refineries and oil transportation facilities. The largest reduction in O&M costs occurs in the Reduced Petroleum Case, where there is an 29 million dollar (8%) decrease in costs. The smallest reduction occurs in the Increased Renewables Case, where there is a decline of 3 million dollars (0.9%) in O&M costs.

BECHTEL ENERGY SUPPLY PLANNING MODEL

04/21/79 RUN 240

TOTAL ANNUAL COSTS (EX FUEL) (MILLION DOLLARS, JAN 1978)*
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES
PERU - REFERENCE CASE/IMPORTS

CATEGORY	ANNUAL REQUIREMENTS					AVERAGE GROWTH RATES (%/YEAR)			
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000
OIL									
EXPLORATION, DEVELOPMENT, & PRODUCTION	10.	21.	21.	26.	(1993)	11.2	8.3	0.1	3.2
REFINING	16.	39.	24.	39.	(2000)	-3.0	3.1	5.7	3.9
PIPELINES	0.	0.	0.	0.	(1988)	-0.8	-1.2	3.5	1.9
TANKERS, BARGES, TRUCKS	3.	6.	4.	6.	(2000)	10.8	-3.9	5.1	3.8
BULK STATIONS	0.	0.	0.	0.	(2000)	-1.7	8.6	5.5	5.2
OTHER	8.	16.	12.	16.	(2000)	11.4	0.0	2.3	2.9
TOTAL OIL	37.	82.	61.	82.	(2000)	5.5	3.7	3.1	3.5
GAS									
EXPLORATION, DEVELOPMENT, & PRODUCTION	0.	0.	0.	0.	(2000)	0.0	0.0	9999.0	9999.0
PIPELINES	0.	0.	0.	0.	(1977)	-2.6	-2.9	-4.3	-3.8
DISTRIBUTION	1.	1.	1.	1.	(2000)	-2.6	2.4	4.0	2.8
OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL GAS	1.	1.	1.	1.	(2000)	-2.6	2.2	4.5	3.0
COAL									
MINING	0.	26.	7.	26.	(2000)	0.0	0.0	9999.0	9999.0
TRANSPORTATION	0.	1.	0.	1.	(2000)	2.3	18.8	8.7	10.0
TOTAL COAL	0.	27.	8.	27.	(2000)	2.3	18.8	40.8	30.1
ELECTRIC UTILITIES									
CONVENTIONAL HYDRO	3.	15.	8.	15.	(2000)	12.6	4.8	6.8	7.1
MINI & MICRO HYDRO	0.	0.	0.	0.		0.0	0.0	0.0	0.0
COMBUSTION TURBINE	1.	2.	2.	2.	(2000)	1.8	11.1	2.7	4.4
DIESEL	1.	2.	2.	2.	(1999)	0.7	11.6	2.7	4.3
OTHER OIL & GAS FUELED	2.	2.	2.	2.	(1977)	0.0	-0.3	-1.0	-0.7
CONVENTIONAL COAL-FIRED	0.	2.	1.	2.	(1992)	0.0	0.0	9999.0	9999.0
SULFUR REMOVAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
HEAT RECOVERY	0.	0.	0.	0.	(1988)	0.0	0.0	9999.0	9999.0
GEOTHERMAL	0.	0.	0.	0.		0.0	0.0	0.0	0.0
NUCLEAR	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER GENERATION	1.	1.	1.	2.	(1985)	0.0	5.5	-4.9	-2.1
TOTAL GENERATION	9.	25.	18.	25.	(2000)	5.2	5.0	4.6	4.8
TRANSMISSION	0.	1.	0.	1.	(2000)	2.0	12.7	4.0	5.6
DISTRIBUTION	1.	3.	2.	3.	(2000)	4.5	8.0	6.3	6.4
TOTAL UTILITIES	9.	29.	18.	29.	(2000)	5.1	5.4	4.8	5.0
OTHER TECHNOLOGIES									
SOLAR WATER HEATING	0.	0.	0.	0.		0.0	0.0	0.0	0.0
OTHER RENEWABLE ENERGY	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL OTHER	0.	0.	0.	0.		0.0	0.0	0.0	0.0
TOTAL ENERGY INDUSTRY	47.	139.	88.	139.	(2000)	5.3	4.0	5.0	4.8

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

Table 4-12

ANNUAL COSTS (MILLION DOLLARS, JAN 1978)*
FOR THE OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES+
PERU - REFERENCE CASE/DOMESTIC

CATEGORY	ANNUAL REQUIREMENTS-----					AVERAGE GROWTH RATES (%/YEAR)				
	1977 (CALC'D)	2000	1978-2000 AVERAGE	PEAK	YEAR	1977- 1980	1980- 1985	1985- 2000	1977- 2000	
NON-MANUAL TECHNICAL LABOR	6.	17.	11.	17.	(2000)	4.7	5.0	4.7	4.8	
NON-MANUAL NON-TECHNICAL LABOR	3.	8.	5.	8.	(2000)	5.0	4.8	4.7	4.8	
MANUAL LABOR	19.	58.	36.	58.	(2000)	5.2	4.7	5.0	5.0	
LABOR TOTAL	28.	84.	53.	84.	(2000)	5.1	4.8	4.9	4.9	
WOOD PRODUCTS (20)	1.	5.	3.	5.	(2000)	5.6	6.0	5.6	5.7	
CHEMICALS & ALLIED PROD. (27,28,30,32)	6.	13.	8.	13.	(2000)	-0.7	1.9	5.2	3.7	
PETROLEUM PRODUCTS (31)	5.	15.	9.	15.	(2000)	4.7	-1.7	7.3	4.9	
GLASS, CLAY & STONE PRODUCTS (35,36)	1.	4.	2.	4.	(2000)	3.2	5.8	7.2	6.4	
PRIMARY IRON & STEEL PRODUCTS (37)	1.	1.	1.	1.	(1997)	0.2	2.9	2.6	2.3	
PRIMARY NON-FERROUS METALS (38)	1.	3.	2.	3.	(2000)	4.4	7.4	5.9	6.1	
FABRICATED STRUCTURAL PRODUCTS (40)	0.	1.	0.	1.	(1997)	0.6	2.7	2.7	2.4	
OTHER FABRICATED PRODUCTS (42)	1.	2.	1.	2.	(2000)	8.7	2.4	6.7	6.0	
MISCELLANEOUS MATERIALS	0.	0.	0.	0.	(2000)	0.0	0.0	9999.0	9999.0	
MATERIALS TOTAL	16.	45.	27.	45.	(2000)	2.7	1.8	6.1	4.7	
HVAC HEATING & COOLING UNITS (52)	0.	0.	0.	0.	(2000)	-2.6	2.4	4.0	2.8	
HVAC DUCTWORK & ACCESSORIES (40)	0.	0.	0.	0.	(1977)	-0.6	0.1	-3.5	-2.3	
TURBINES (43)	1.	0.	1.	1.	(1977)	-0.6	-0.1	-3.7	-2.5	
GAS WELDING SETS (47)	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
ELECTRIC WELDING SETS (53)	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
CONSTRUCTION, MINING & OIL FIELD EQP (45)	0.	0.	0.	0.	(1992)	9.6	14.5	0.6	4.6	
MATERIALS HANDLING EQUIPMENT (46)	0.	0.	0.	0.	(1998)	1.4	9.0	8.9	7.9	
GENERAL INDUSTRY EQUIPMENT (49)	2.	4.	3.	4.	(2000)	3.7	3.1	4.0	3.7	
INSTRUMENTATION & CONTROLS (62)	0.	0.	0.	0.	(2000)	8.2	1.8	4.2	4.2	
ELECTRICAL EQUIPMENT (53,55)	2.	7.	4.	7.	(2000)	4.5	7.6	6.7	6.6	
FABRICATED PLATE PRODUCTS (40)	0.	0.	0.	0.	(2000)	6.3	1.2	1.5	2.1	
MISCELLANEOUS EQUIPMENT	3.	12.	8.	12.	(2000)	11.1	9.3	5.2	6.8	
EQUIPMENT TOTAL	7.	24.	15.	24.	(2000)	6.4	6.7	5.0	5.5	
ELECTRICITY	7.	17.	10.	17.	(2000)	-2.2	2.6	5.7	3.9	
NATURAL GAS	0.	0.	0.	0.	(1992)	3.9	2.3	1.7	2.1	
WATER	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
UTILITIES TOTAL	7.	17.	10.	17.	(2000)	-2.2	2.6	5.7	3.9	
RENTS, ROYALTIES, ETC.	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
ALL TAXES	0.	0.	0.	0.		0.0	0.0	0.0	0.0	
SERVICES & MISCELLANEOUS	13.	38.	25.	38.	(2000)	7.0	5.2	4.4	4.9	
ANNUAL OPERATING COST (EX FUEL)	70.	207.	130.	207.	(2000)	4.4	4.3	5.1	4.8	
CURRENT DOLLAR ANNUAL COST **	65.	916.	342.	916.	(2000)	11.7	11.6	12.5	12.2	
CONSTANT DOLLAR ANNUAL COST **	70.	207.	130.	207.	(2000)	4.4	4.3	5.1	4.8	

A GROWTH RATE EQUAL TO 9999.0% IMPLIES INFINITE GROWTH

BEA (BUREAU OF ECONOMIC ANALYSIS) TWO-DIGIT CATEGORIES ARE IN PARENTHESIS.

+ INCLUDES REQUIREMENTS FOR ENERGY SUPPLY AND TRANSPORTATION FACILITIES

* COSTS ARE IN REAL 1978 DOLLARS. REAL DOLLARS ARE COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS, THEN DEFLATED USING THE SPECIFIED PROJECTED GNP DEFLATOR.

** COMPUTED USING BASE YEAR COSTS ESCALATED BY SPECIFIED ESCALATION FACTORS.

** COMPUTED USING UNMODIFIED BASE YEAR COSTS.

Table 4-12 (Continued)

Table 4-13

COMPARISON OF IMPACTS OF ALTERNATIVE ENERGY STRATEGIES
ON OPERATIONS AND MAINTENANCE COSTS IN THE YEAR 2000
(in millions of January 1978 dollars)

Energy Sector	Reference Case	Increased Energy Efficiency		Increased Renewables		Increased Hydro		Increased Coal		Reduced Petroleum	
		Cost	Change	Cost	Change	Cost	Change	Cost	Change	Cost	Change
Oil	191	169	-22	180	-11	171	-20	180	-11	137	-54
Gas	4	4	-	4	-	4	-	4	-	4	-
Coal	51	51	-	51	-	51	-	72	+21	65	+14
Solar	-	-	-	8	+8	-	-	-	-	8	+8
Electric Utilities	100	101	+1	100	-	96	-4	100	-	103	+3
o Hydro	27	29	+2	27	-	31	+4	27	-	31	+4
o Other	34	33	-1	34	-	26	-8	34	-	33	-4
o Transmission & Distribution	39	39	-	39	-	39	-	39	-	39	-
TOTAL	346	325	-21	343	-3	322	-24	356	-10	317	-29

INSTITUTIONAL STRUCTURES WHICH MIGHT BE
USED BY DEVELOPING COUNTRIES TO PERFORM
ENERGY PLANNING, POLICY-RECOMMENDATION,
R&D AND PROGRAM MANAGEMENT

A CASE STUDY USING THE
REPUBLIC OF PERU

BY
ERECON CORPORATION

SEPTEMBER 1978

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SECTION I

Introduction

INTRODUCTION

In September of 1977 President Carter initiated a pilot program aimed at assisting developing countries to meet their future energy needs with indigenous energy resources and appropriate energy alternatives. The program recognizes the critical role that energy plays in economic and social development and the difficulties that many developing countries now face in meeting their energy needs at acceptable costs.

Two countries are involved in the pilot phase of the program, Egypt and Peru. They were chosen on the basis of interest in collaborating in a pilot program and the availability of indigenous energy resources. *

As the Peru-U.S. Cooperative Energy Assessment progressed, awareness developed of its future implications in terms of organization and programs. This in turn led to concern on the part of the host country as to whether or not its existing institutions could effectively carry out the actions indicated by the assessment. The host country suggested the need for an examination of institutional structures which a developing country might use to perform energy analysis, planning, policy-recommendation, R&D and program management. The suggestion was adopted and this report reflects the results of the examination using Peru as an appropriate case.

The report is considered to be a draft (preliminary) statement in view of the short time for the study (under six weeks) and its confinement to the United States. However, much has been achieved through extensive efforts in the United States. These include review of some forty publications related to the subject matter and interviews with approximately thirty people familiar with various aspects of the questions. Especially helpful have been various preliminary analyses prepared by the U.S. Department of Energy, and personnel of its Argonne and Brookhaven National Laboratories, as well as energy resource reports by the U.S. Geological Survey, the U.S. Bureau of Mines and U.S. Bureau of Reclamation. Also especially helpful have been insights and advice received through discussions with key personnel in the U.S. Agency for International Development (U.S. State Department), the Organization of American States, and the U.S. Department of Energy. Sources of information are given in the references in the Appendix.

We believe this draft statement represents a reasonably sound basis for consideration of the possible institutional approaches to energy planning, policy-recommendation and program implementation in Peru and for the necessary further study and discussion of the many various elements and issues involved. Recommendations in these respects are included.

* Reference 2

SECTION II

Summary

SUMMARY

The first assignment for this study was to define the current situation in Peru in respect to energy policy-making and planning based on available information.

The second assignment was to "identify several organizational structures which might be used by a developing country, such as Peru, to establish an institution capable of performing energy planning, policy-recommendation, R&D and program management."

The assignment was to include appropriate functions and estimated costs for such an institution.

The first assignment:

In regard to defining the current situation in respect to energy policy-making and planning the study shows that these functions are vested in the National Planning Institute, a primary staff office reporting to the President of the Republic. This office provides directives for the formulation of National Development plans within which national energy plans are developed. An energy section within the office is responsible for "conducting and coordinating the process of formulation of the energy sector plans, which are elaborated with the participation of all institutions related to the energy sector." *

The primary sources of energy information for the planning office are the Ministry of Energy and Mining, the Ministry of Tourism, Industry and Commerce, and the Ministry of Transportation. Each of these ministries has a small planning section of its own. Of the three, the most significant from the viewpoint of energy is the Ministry of Energy and Mining since it not only controls the oil, hydroelectric and coal resources but also is the principal supplier of their energy production.

Present information indicates that a well-coordinated energy planning and implementation strategy has yet to be developed, especially in respect to private industry and to new directions such as renewable energy resources. However, as shown in the discussion in Appendix A, a reasonable core of current and projected plans has been worked out and this is being improved through ongoing planning efforts, including those involved in the joint Peru-U.S. energy assessment program.

The second assignment:

In order to satisfy the assignment in respect to an "institution" for energy planning, policy-recommendation and program management, it was considered fundamental to first identify the tasks (functions) which the institution is to perform, the social and economic environment with which it must be compatible and the role of energy within this environment.

* Appendix A

In respect to the social and economic environment, the following two statements are basic:

The country is experiencing a period of economic hardship with a resultant severe shortage of funds for both capital and operating requirements.

There are major social problems such as the serious substandard living conditions in the rural areas and in the "young villages" in the urban areas. The need to alleviate these problems holds a high priority in the competition for the limited development funds.

In respect to the role of energy within the social and economic environment, the following perspectives are apparent:

The real significance of the energy situation in Peru rests in the potential for a sound energy planning, management and development program to play a substantial role in relieving the serious social and economic problems. The country is currently meeting the demand for energy and apparently has the energy resources to provide a large portion of the supplies needed for the future, provided the substantial capital funds can be obtained and strategic development efforts pursued.* Yet, increased energy supplies and increased efficiency of energy use must be achieved if the social and economic goals are to be met. Examples of this energy role are:

Conservation in use of petroleum for industrial energy can assist in providing petroleum exports to earn critically needed income.

In the rural areas, energy which can provide safe drinking water, which can further provide irrigation water necessary for proper food to relieve nutritional shortages and which could provide a basis for "cottage" industries could contribute much to improved health and future prospects for the rural population. This would ease one of the most pressing social problems.

In respect to the tasks (functions) for which the institution must be designed the study sets forth the following conclusions:

The two primary functions required for the energy "institution" are:

* Reference 3

Planning: The development of energy plans and policies through complex analysis of energy supplies and energy demand as influenced by such factors as the economic situation, technology potentials, extent of natural resources, energy conservation potential, social imperatives, etc.

Implementation: The actions required to insure that energy plans and policies are fulfilled. These include the use of applied technology to provide for increased efficiency in the use of energy as well as the technology for development of renewable energy resources, etc. They include the adoption of the "program management" approach (defined later) to implementation of new energy projects.

The foregoing discussion summarized the conclusions of the study in respect to the constraints which would be placed on the "Energy Institution" by the social and economic imperatives, the potential role of energy for improving the social and economic situation and the basic planning and implementation requirements which the institution must meet.

With these conclusions in mind, the study then fulfills its second assignment by outlining six organizational arrangements under which an "Energy Institution" might be set up. These six can be simplified to three basic options:

- 1) Maintain current organizational structure in respect to energy planning and program management but with efforts to strengthen the personnel and practices in both planning and program management areas.
- 2) Set up an energy "Authority" which would operate within the government and would have a Board with membership from key ministries concerned with energy supply and use, from the National Planning Institute and from the private sector. The "Authority," given national economic, social and resource guidelines by the National Planning Institute, would be responsible for energy plans and policy recommendations, and for the actions required to insure that those plans and policies were fulfilled in regard to new energy initiatives - such as those involved in the development of much greater use of renewable resources.
- 3) Set up a private, non-profit "energy institution". This "Institution" would have a Board of Trustees of considerable stature in the various areas

related to energy and would have the organizational infrastructure necessary to provide high quality energy planning and policy formulation, together with effective implementation of the plans and policies in new initiative areas. This institution would obtain its own operating staff funds and project funds from a variety of sources such as various foundations, private firms, international development banks, etc.

Positive and negative factors in respect to these approaches are outlined in the report.

Finally, the report provides a brief discussion of estimated costs associated with the above, provides a series of recommendations directed toward effective energy planning and program implementation operations, and suggests questions which need further study. A substantial amount of supporting information is furnished in the Appendices.

SECTION III

Statement
of the Assignment

Scope

The contract requests a feasibility study of the potential for establishment of a planning and policy recommending institution and any additional institutions which may be needed to effectively address a developing country's energy needs and resources.

The contractor will deliver to the laboratory.

A draft technical report covering the work outlined below to be received by the Laboratory no later than September 30, 1978.

Technical Tasks

The contractor shall provide the personnel to perform the following services:

Define the current situation in Peru in respect to energy policy and planning based on available information.

Identify and develop several organizational structures which might be used by Peru to establish an institution capable of performing energy planning, policy-recommending, R&D and program management.

Define appropriate functions and estimate costs for such an institution.

SECTION IV

The Basis for the Institution Type and Structure

THE BASIS FOR THE "INSTITUTION"
TYPE AND STRUCTURE

It is fundamental that any such institution as is being considered here must be so designed as to handle efficiently its special functions within the environment (political, social, etc.) in which it must operate. In effect, the tasks and the environment will dictate institution type and structure. Thus, while examination of similar institutions in other developing countries is worthwhile and has been done during this study, the ultimate institution for a developing country, such as Peru, will need to be tailored to the special situation in that country.

The following discussion, then, will examine first the environmental factors which are fundamental to the "institution"; second, the current government structure related to energy; third, the functions or tasks which the "institution" must handle; and, finally then, the organizational structures which might be set up to handle those tasks in that environment.

SECTION V

Basic Elements with Which the
Institution must deal in Peru

The "Environmental" Realities Affecting An Energy
Planning, Policy-recommending and Implementation
"Institution" in Peru

The authors of this report have examined a substantial number of reports, books and other publications dealing at length with the social, political and economic situation in Peru, and dealing with assessment of the current and projected energy supply and demand situation in that country. They have also examined similar situations in other developing countries such as Korea, Colombia, Guatemala, Brazil and Venezuela. Further, they have discussed many of the issues involved with a large number of informed people including those from U.S.A.I.D.; U.S. Department of Energy; the World Bank; the O.A.S., etc. From these sources, a summary of the "environmental" factors affecting the "energy institution" can be put forward.

Despite advances made toward national development, significant obstacles to economic and social development persist in Peru:*

- Economic, social and cultural disparities are great. Nearly eight million people live in rural areas with extremely low per-capita annual incomes, ranging in the highlands from \$75 to \$115.
- The country's almost seven million Indians historically have been largely isolated or alienated from the national society because of language barriers and inadequate access to education and training.
- Overall health status and nutritional intake, especially for the millions of rural families and urban "young town" dwellers, are among the lowest in South America.
- There is a shortage of skilled administrators and trained technicians; meanwhile, underemployment and unemployment are high, reaching 50% in the highlands.
- The population growth rate is high (about 44 per 1,000), and creates a real burden on health, education and other national economic and social facilities.

* Peru, Country Background Information

- Land for cultivation and water for irrigation are very scarce in the heavily populated coastal and highland areas.
- Agricultural production remains persistently low, being outstripped by the high population growth rate, resulting in food shortages and increasingly large food import bills.

The Peruvian economy has not yet responded to major and overdue economic adjustments made in June 1976.*

- The rate of inflation (35%) continues at historically high levels.
- Peru's balance of payments position continues to be critical, with the trade deficit projected to be in excess of \$800 million. Major external borrowings have been necessary.
- The overall economic growth rate has been about 2%, compared with an average growth of 6% during the period 1973-74.

Peru has current energy supplies sufficient to meet current needs. In addition, there are adequate prospects for energy supplies in the future through potential increases in the development of oil, coal, and hydroelectric resources, together with geothermal energy and the renewable resources of wind, solar hydropower and biomass.

* Peru, Country Background Information

These social and economic realities, together with assessment of the energy situation, lead to the following conclusions in respect to energy:

- Peru is not faced with energy scarcity, provided it continues to develop its resources and the necessary associated distribution systems.
- The importance of the energy situation lies in its key relationship to the social and economic needs of the country. Thus, measures such as conservation of energy and substitution of alternate energy sources for domestic oil consumption provide the needed opportunity to export hydrocarbons and thus improve the highly unfavorable balance of trade.

The social imperatives of the rural areas where, as noted, over 40% of the people live under harsh and restricted conditions, dictate high priority national attention, including energy priorities. The problems of these areas are unique in that, in general, they don't have access to power supplies, their population is dispersed, and the livelihood of the people depends on a precarious, meager agricultural base.

Energy which can ease their problems, providing hope for the future, can be a vital factor in improving the nation's social development. Such energy can provide prospects for adequate drinking water of vital importance in improving health. Likewise, it can be used to provide water for agricultural purposes (animals and crops) which would offer prospects, then, for the basic need for improved nutrition, for improvement in living standards, and for productive occupation of the people. It may also assist in providing prospects for productive occupation of the people (in turn, decreasing migration to the urban areas) through providing energy for "cottage" industries.

Energy can help solve the problems of the cities (pueblos jovenes--young villages) where primitive living conditions prevail through the lack of electricity, paved roads, safe drinking water and satisfactory shelter.

The critical current economic situation severely limits the funds (both capital and operating) available for national development. Thus, the need for energy development funds must compete with other national needs for the same limited funds. This, in turn, means that all projects will be subject to a severe imposition of priorities and a tendency for the near-term priorities to override the mid-term and long-term requirements. Likewise, the same problem may well make it difficult to obtain needed project support in the rural areas where progress can be slower and political pressures more disperse than in the urban areas. The shortage will also place a strong emphasis on measures which can obtain "external funds"--(i.e., foreign government support, foreign industry loans, cost-sharing arrangements, etc.).

SECTION VI

The Current Energy Planning,
Policy-Recommendings, R&D and
Implementation Structure

The Current Energy Planning,
Policy-Recommendings, R&D and
Implementation Structure

Energy plans and policy-making functions centralized in the National Planning Institute (NPI) reporting to the President. Input to NPI, as shown by the following organizational diagram (Fig. 1) can come from several ministries and special agencies of commissions. (These generally have their own small planning nuclei). The principal ones concerned with energy are:

The Ministry of Economics and Finance is responsible for overall economic development.

The Ministry of Energy and Mines has broad operating responsibilities in the areas of petroleum resources and supplies, electric power and coal mining. This ministry oversees also the nuclear energy field and the geological and mining services. It has a number of technical organizations to assist it, the primary ones being:

INIE: Research Institute on Energy and Energy Services

INCITEMI: Mining Science and Technology Institute

IPEN: Peruvian Institute for Nuclear Energy

INGEOMIN: Geology and Mining Institute

The Ministry of Tourism, Industry, and Commerce (MITIC) along with its general responsibilities for tourism, industry, and commerce is concerned with energy demand and use in these sectors. The ministry has three technical organizations to assist it. They are:

ITINTEC: Institute for Industrial Technology and Technical Standards.

SENATI: National Service for Training and Industrial Works.

INDIPRO: Institute for Training and Industrial Development.

The Ministry of Transportation and Communications

The Office for the Evaluation of Natural Resources. (ONERN)
It is understood that this office is also in charge of environmental rules. It reports to the National Planning Institute.

PRINCIPAL ENERGY RELATED INSTITUTIONS
IN PERUVIAN GOVERNMENT

Figure 1

There are other ministries and agencies which have inputs to energy supply, demand, planning and policy-making questions. These include:

- Ministry of Food
- Ministry of Fishing
- Ministry of Education
- Ministry of Agriculture

Their technical organizations are charted and described in the Appendix.

The preparation of present energy plans and policies is summarized in Appendix A in a paper entitled "Energy Sector in Peru: Actual Situation and Perspectives."

This paper explains that national energy plans are formulated as part of National Development Plans prepared under the National Planning Institute. It also outlines the current energy situation and the status of present and future plans and policies.

Improvements in respect to planning, policy-making and implementation.

The joint U.S.-Peru energy assessment effort indicates that there are a number of important areas of energy planning, policy-making and implementation which need further study and possible implementation. These include especially the actual prospects for the use of Peruvian coal, the true potential oil and gas in the Amazon basin and the contribution potential and schedules for renewable energy resources: (small hydropower, wind, solar, biomass, geothermal).

The assessment also suggests that improvements are needed in energy planning, policy-making and implementation. The improvements are primarily in the direction of better overall coordination of energy plans and programs, a stronger "systems" approach to energy planning and policy-making, and more initiatives in respect to new directions. These factors are discussed in a later section of this paper.

Technology

In carrying out the applied technology concerned with current operations, with new developments and with technology "delivery" the primary technical teams appear to be as given earlier:

In the Ministry of Energy and Mines:

INIE

INCITEMI

In the Ministry of Tourism, Industry and Commerce:

ITINTEC

SENATI

Based on available information, the functions of these institutions are:

INIE: To prepare studies on electrical power development and power plants.

INCITEMI: To carry out research and development in the mining field, to advise the ministry and to set standards in mining.

ITINTEC: To promote, coordinate and guide science and technological research related to industrial development; to prepare and set quality standards providing quality seals of approval; to provide information related to industrial technology.

SENATI: To provide training and development of skilled workers, technicians and lower and middle level managers in the industrial sector. In operating as a large vocational training center it operates a number of special shops (such as machine, woodworking, electronic, etc.) which can also serve as prototype production units.

The extent to which these technical organizations can play a leading role in energy analyses, planning and program implementation is not clear from publications or comments currently available in the U.S. The evaluation of this question together with consideration of possible advisable modifications to these organizations calls for more time than is available for this study and, further, calls for direct study and discussions in Peru itself. However, Appendix B supplies a useful discussion of their current functions and budgets.

SECTION VII

Functional Characteristics of an "Institution"

Capable of Energy Planning,
Policy-Recommendation, R&D, and
Program Management

Introduction

The second of the technical tasks requires that the contractor develop several structures which might be used by Peru for an energy institution capable of performing energy planning, policy-recommendation, R&D and program management. As noted, the design for such an institution must take account of the present Peruvian government structure as well as the economic and social environment of the country, and the problems with which it must grapple. A brief summary of these elements has been given in the previous section. As in most organizational designs, there is no unique solution. There are, however, a number of functions such an organization must fulfill regardless of its relationship to the larger government structure.

General Functions of the Energy Institution

Two primary functions are required. They are planning and implementation:

Figure 2 shows the functions required to make and implement energy plans and policies.

FUNCTIONS REQUIRED
TO MAKE AND IMPLEMENT
ENERGY PLANS AND POLICIES

Figure 2

National plans and policies provided by overall government planning must be transferred into corresponding energy plans and policies.

This requires that an "institution" to do this possess the capability to make a continuous assessment of demand forecasting through the use of appropriate models in the principal sections of the economy such as agriculture, transportation, housing, industry and commercial establishments. Correspondingly, there will be required a continuous assessment and forecast of the natural resource and supply base in terms of hydrocarbons, hydropower, nuclear, geothermal, biomass, solar and wind energy.

But the supply and demand potentials will be the result of interaction with the various energy technology potentials and key economic elements such as the current economic situation, capital requirements for energy and other national needs, tax policies, and private sector incentives. They will likewise vary with export-import policies, societal imperatives, alternative options for resource use and the degree of environmental restraints imposed.

Thus, the ultimate implementation plans, including their priorities and time-phasing, comprise an energy strategy developed through evaluation of the complex interactions of the above variables on present and future energy supply and demand possibilities.

The development then of energy strategy can be shown as in Figure 3.

Implementation

The second primary function of an energy "institution" is that of initiating and managing the actions required to insure that energy plans and policies are fulfilled. The institution must have the capability of carrying out new initiatives in applied technology, spearheading financial arrangements for new initiatives, and providing overall program management for the new initiative projects.

These tasks in themselves can be quite complex. It therefore becomes most important in view of the difficult economic situation to insure that tightly organized structures are set up to handle them and that these structures be staffed by highly competent and experienced personnel. Thus, for example, the applied technology group is involved not only in helping to appraise and formulate energy plans and policies but also in providing strong assistance in putting together sound action measures in energy conservation and energy conversion systems. It further plays a key role in the exchange of valuable technical information. In the industrial area alone waste energy utilization, process changes and

Figure 3
VII-4

materials optimization options when evaluated across industry sectors provide a complex matrix for evaluation. Such a matrix is shown in Appendix I to illustrate the significance and scope of the applied technology function.

The implementation functions are diagrammed in Figure 4. Discussion of the infrastructure associated with these functions and those of the planning functions follows the next section on organizational placement of the institution or its major elements of planning and implementation.

Figure 4
VII-6

SECTION VIII

Organizational Structures

With the preceding functional characteristics in mind for energy planning, policy-recommendation and implementation, we turn now to consideration of possible organizational arrangements which would encompass these functions.

ORGANIZATIONAL STRUCTURES
FOR ENERGY PLANNING,
POLICY-MAKING, R&D, AND
IMPLEMENTATION

Option 1:

Separate Planning and Implementation Ministry (MEPPI)

Positive:

- Provides for coordinated energy planning and coordination of planning with implementation.
- Reduces inputs to NPI simplifying energy coordination with that office.
- Provides for support, coordination and management of new directions (i.e., use of renewable energy sources).

Negative:

- Possible conflicts with other ministries or NPI.
- Requires complexities of setting up and staffing new Ministry.
- Possible over-emphasis of energy issues as against other national requirements.

NPI = National Planning Institute
MEM = Ministry of Energy and Mines
MITIC = Ministry of Tourism, Industry and Commerce

*Includes possible contractual assistance by outside groups.

ORGANIZATIONAL STRUCTURES

Option 2:

All Energy Functions in One Ministry, such as MEM

Positive:

- Provides for maximum coordination of energy planning and programs.
- Can build on existing organizational structure.

Negative:

- Possible conflicts with other ministries.
- Operating (production) pressures may pull support from planning efforts and implementation of new directions.

NPI = National Planning Institute
MEM = Ministry of Energy and Mines
MITIC = Ministry of Tourism, Industry and Commerce

*Includes possible contractual assistance by outside groups.

ORGANIZATIONAL STRUCTURES

Option 3:

All Planning In NPI; Implementation in MEM

Positive:

- Pulls all planning together.
- Builds on current organizations.
- Probable minimum changes to present system.

Negative:

- Splitting planning and implementation functions can lead to poor coordination of the two functions and schisms between planners and "doers".
- Possible conflicts in implementation area with other ministries.

NPI = National Planning Institute
MEM = Ministry of Energy and Mines
MITIC = Ministry of Tourism, Industry and Commerce

*Includes possible contractual assistance by outside groups.

ORGANIZATIONAL STRUCTURES

Option 4:

Stay with Present Organization

Positive:

- Does not require changes in government structure during period of pressing national issues (i.e. economic stresses).
- Consideration can be given to strengthening planning nucleus in each ministry and energy planning capability in NPI.
- Improved energy plan implementation and coordination may be possible through budgetary controls granted NPI.

Negative:

- Present organization has reportedly not provided adequate overall energy planning and coordination especially in respect to "systems effects" and new directions.
- The need for energy program management and coordination will probably not be solved by budget controls alone.
- Overall energy program leadership is missing under this approach; leadership is splintered.
- Present organization does not have responsibility for planning or evaluating energy use in transportation or industry.

*Includes possible contract assistance by outside groups.

ORGANIZATIONAL STRUCTURES

Option 5:

Set up a special energy "Authority":**

Has overall authority for energy planning and implementation. (New directions.) Reports to President's Office. Chairman and Board of Directors appointed by President. Board members include heads of implementing ministries (MEM, etc.). Also include Head of NPI and four members from private sector.

Positive:

- Provides for full coordination of energy planning, policy-making and R&D and for coordination and control of implementation of new directions.
- Planning can be more realistic through more direct participation by operating groups.
- Implementation success more likely if operating people are included in planning and policy-making.
- Drawing in private sector assures a more overall national program.
- The public-private make-up of the "Authority" fits the current industrial division between public and private sectors.
- "Authority" can have easy transition to civilian government.

*Includes possible contractual assistance by outside groups.

**Summary Charter given in Appendix C.

Negative:

- This approach would require a new special structure in the government and the complexity of arrangements for it.
- The approach can result in more cost of government at a time of economic hardship.
- There is the question of a special energy agency in the light of other critical national issues. Economic and social issues are more broadly critical.

Organizational Structures

Option 6:

Set up a non-profit private corporation for energy analysis, planning and implementation.

This might be called the Energy Institute or the Institute for Developing Energy Alternatives.

While this organization would not have direct authority within the government, the intent would be to organize an "institute" of the finest quality and integrity such that its plans would receive serious consideration both within and outside the government and so that its implementation of new energy initiatives could provide optimum results within minimum times and costs.

Positive

- This Institute can be designed to optimize its chance of success for fulfilling its purpose.
- It would be independent of current organizational limitations, especially those within the government.
- It can draw on the highest caliber of personnel for staff and Board, including all desirable sectors.
- Board members can be drawn from outside of the government and in certain cases from outside the country. It can also draw on uniquely capable members for working sub-committees.
- It can be designed to have a substantial capability for fund-raising to support its initiatives - and thereby relieve the government of a portion of its fund-raising requirements.
- It has the potential for minimizing the time for significant practical accomplishments.

Positive (continued)

- It can avoid the limitations of current civil service structure, including pay scales, and thus provide improved incentives for attracting outstanding personnel.
- It can control the synchronization between its planning and implementation groups.
- It would have an easy transition in the event of a change from a military to a civilian government.

Negative

- Its planning and policy recommendations might not be welcomed or accepted by the government.
- Coordination with various government operating groups with whom its planning and implementation functions might be intertwined could be difficult or at least inefficient.
- Because of its private nature, it could not serve in the overall rôle of planning and management of the Peruvian energy program. This role would have to be played by an entity within the government.
- Since it would be set up separately from the government, it would have to find all or most of its own funding including that for its own projects.
- In certain cases its fund-raising could be limited by its "private" status.
- It could find itself competing with government groups for funds from the same outside sources which in turn could result in problems for government policy-makers.

Since this Institution is unique in respect to those considered thus far, the following comments will provide more insight into its nature. In addition, it is described more thoroughly in Appendix D.

Institute for Developing Energy Alternatives

The final option portrays an institution which is positioned in the private sector and possesses the following essential properties:

- 1) It is a non-profit private corporation.
- 2) It functions under policy set wholly by an autonomous board of trustees.
- 3) It raises its own working capital from a variety of sources including government grants and contracts, international agencies, banks, private foundations and industry.
- 4) Like any private corporation, staffing is based on competency and proven experience free from the normal civil-service restrictions of government ministries and agencies.
- 5) It is primarily a planning and program implementation institution which funds and oversees projects carried on by other external institutions.
- 6) External project management institutions such as universities, industry, government agencies and research institutes are selected by a "best performance" criterion.
- 7) At a later stage in the evolution of the Institute for Developing Energy Alternatives, an in-house "hands on" laboratory may be created to permit organization to retain and up-grade the technical competence necessary for high quality in planning and program management.
- 8) Wherever possible, contracts, grants or other funding arrangements will provide for a fee of approximately 10% in order to build up working capital for proposal preparation and non-sponsored initiatives deemed important by the board of trustees.
- 9) The corporation is designed to spearhead new initiatives. It would continue to find and manage these initiatives until such time as they reach maturity and can be handed off to an industrial or governmental operating entity.

SECTION IX

Approximate Institutional Costs for the Planning and Implementation Elements

Costs

Assuming that a separate energy planning, policy-recommendation and implementation institution is set up, operating costs could be approximately as follows:

Assume a careful start with a strong nucleus. The first year nucleus might consist of eight people in the planning area and 10 in the implementation area, with additional assistance from the Applied Technology Laboratories. It is also estimated that the planning element might build up to 15 in five years and the implementation element might build up to 100. Current annual costs for engineers in Peru, on the basis of available information (see Appendix), appear to vary from around \$3500 for a junior engineer to \$18,000 for a senior engineering manager. Taking \$12,000 per year as the average for our planning and implementation groups, we can estimate first year and 5th year costs as follows:

First year operating costs:
(not including programmatic costs)

:	:	Annual	:	G&A	:	:	:	:Mat'ls	:
:	Staff:	Staff	:	and	:	:	:	&	Total
:	No.:	Sals.(\$)	:	Overhead:	Travel:	Computer:	Supplies:	:	\$
P:	8	:	96K	:	45K	:	15K	:	15K : 5K : 176,000
I:	10	:	120K	:	60K	:	25K	:	15K : 10K : 230,000
									TOTAL \$406,000

These need not be all new costs to the government since it should be possible to draw some of the personnel from current organizations.

Fifth year annual operating costs:
(not including programmatic costs)

:	:	Annual	:	G&A	:	:	:	Mat'ls	:
:	Staff:	Staff	:	and	:	:	:	&	: Total
:	No.:	Sals. (\$)	:	Overhead:	Travel:	Computer:	Supplies:	:	\$
P:	15 :	180K	:	90K	:	30K	:	25K	:
I:	100 :	1,200K	:	600K	:	100K	:	25K	:
			:		:		:		:
			:		:		:	TOTAL	: \$2,360,000

These costs are based on the assumption that the "institution" is a planning, policy-recommending and implementation organization only; that it involves only staff and offices; and, that all hands-on applied technology and other program activities are carried out in facilities of government agencies, industrial organizations, and universities. Programmatic costs are budgeted separately under program line items.

The staff and costs for such an organization obviously can vary widely depending on numerous factors such as success of programs, funds available for development (capital and operating), number of promising projects, etc. Some comment has been received that costs for the key personnel involved could approximate \$25-30,000/year. If so, the \$12,000 average used in the preceding chart can be too low. Only further study of the salary situation in Peru and more specific determination of work scope and projects will permit closer evaluation of the planning and implementation costs.

Note: 25% of the staff for planning and implementation could be on two-year rotational assignments from universities, laboratories, industry and other government agencies. This permits drawing on those sources for talent and for training those who can go back to their original areas with a broader viewpoint to factor into their operations sound energy considerations.

If the planning and implementation phases are not in a single authority, costs could be somewhat higher due to minor differences in efficiency but the numbers given here are still considered applicable, especially in view of other uncertainties involved.

SECTION X

Infrastructure Associated With ,
Planning and Implementation Efforts

Infrastructure Associated With Planning and Implementation Efforts

The preceding discussions have pointed out the functions to be supplied by an "institution" capable of performing energy planning, policy-recommendation, R&D and program management. The discussions have further pointed out several organizational structures for such an institution. While this study in its brief period cannot go into depth into the organizational sub-structures, nevertheless it can briefly point out basic infrastructure elements with particular attention given to those elements, such as the program management function, which can be of special assistance in providing the most efficient energy planning and implementation efforts.

Program Management

The program management function is an important element of the implementation process in all of the options described. In this function and in his particular program area the program manager is responsible for planning and programming, including the preparation of budgets, as well as overseeing in a programmatic sense, all project managers in a given program. He must have awareness of the various public and private institutions, including their interrelationships, which will play a part in his programs. He is in a unique position in the delivery process, being at the transition between hardware development and operations. He is also involved with the associated social and political elements. Therefore, he must not only have a high degree of technical skill and knowledge but must also be a competent planner and a manager who understands the political, governmental and private environment in which he must function.

A useful and more complete discussion of the program management element is given in Appendix F

Applied Technology Laboratories

The applied technology laboratory can be a key element in the structure for planning and implementing development strategy including that in the energy area. It has come to play an important role in many of the developing countries including Korea, Brazil, Columbia, Guatemala, Venezuela and Pakistan. It must have engineers and scientists with the capability to seek out and interpret technology available from other countries, with the capability to use their technical insight to provide

Applied Technology Laboratories (continued)

sound advice to the planning operations, and; with a special interest and capability for the practical application of technology. However, it must be emphasized that the laboratory should also have in its own structure, or a closely allied structure, experienced anthropologists and economists to insure in concert with the scientists and engineers a soundly balanced approach to planning and program operations. An additional function of the laboratory, or an associated laboratory, is the setting of technical standards for materials, products and test methods for in this way materials and products can achieve necessary universal exchange in international markets.

It is worth special note that the phrase "practical application of technology" includes the meaning of the term "appropriate technology" for it has often been found that imported technologies, at least in unmodified form, are not best suited for the resource situation and social conditions in the importing country. This factor underscores the need for a qualified applied technology laboratory in a developing country to translate the technology information into applications which are properly consistent with the local social, economic, political and resource conditions.

A more complete discussion of the role of the applied technology laboratory is given in Appendix G . Specific examples of such laboratories in Central America, Korea, Brazil, Venezuela and other countries are given in Appendix H . The publication by James Blackledge (Reference 27) from which these examples were taken is a very useful discussion of the "Industrial Research Institute In A Developing Country". The National Research Council publication "Appropriate Technologies For Developing Countries" (Reference 11) is also worthwhile reading on the question of appropriateness as are similar insights presented in other references given.

It is not the assignment of this report to discuss these laboratories in depth, but it is within the assignment of this report to point out the need for such capability in the implementation infrastructure. It is suggested that those technical laboratories in Peru which could fill this need be evaluated for their capability to do so and for modifications which might be called for to strengthen the capability.

Financial Planning and Implementation

The planning and implementation in respect to financial factors is seen to cover a wide range from national capital supply questions to public and private loans, cooperative development

Financial Planning and Implementation (continued)

arrangements and private sector incentives. The degree of the financial issue will obviously dictate the structure for handling it. Thus, major financial issues will obviously require advice and handling by the most senior members of the "Energy Board",* the National Finance Ministry, Development Bank or other appropriate agency. A contract office associated with the Applied Development Laboratory or a program management office can handle many of the cooperative development arrangements or private sector incentive agreements. Public and private loan arrangements on a modest scale can be handled by the program management office working in concert with financial personnel in a contract office and various loan sources such as those in development banks. The very large loans, as with the other large financial issues, would require handling by the senior financial officers in the private and government organizations. In the case of the private, "non-profit" institution (Option 6) senior financial management and implementation assistance of the type required could be furnished via the special finance committee. This committee can be most valuable in pointing out appropriate sources of funds and in assisting in efforts to obtain such funds.

Manpower Development

The quantity and quality of manpower required and the assurance of continued strength of the organizational elements points up the need for a small but strong manpower development office. This office would be responsible for providing continuing senior attention to the means of providing for the necessary qualified personnel including administrators, scientists, engineers, sociologists, economists, technicians and field personnel. The office would not only be charged with a lead role in the planning and procurement assistance for obtaining such personnel but in developing the financial and other incentives for holding them and the training programs for maintaining and improving their capabilities.

Regulations and Environmental Protection

It is understood that these functions are now located in the National Office for the Evaluation of National Resources which reports to the National Planning Institution. This would seem to be an appropriate place for these functions which need only be of modest size at this point in Peruvian development.

*Energy Boards are indicated in Organizational Options 5 & 6.

Regular Operations

It has been pointed out that the regular operations (i.e., Electroperu, Petroperu) would continue in their normal roles and organizational positions and would not, therefore, fall within the implementation structure of the "Institution" being considered in this paper. However, since they would be playing the lead role in current energy resource handling, resource supplies and energy use, coordination at the planning level with their operations is important. Likewise, in implementing new technologies, the Program Managers would be required to coordinate with appropriate regular operating groups not only because of the value of their advice but also because of potential need for their participation in the project "delivery process".

SECTION XI

Comments and Recommendations

Comments and Recommendations

With the preceding material in mind in respect to energy planning, policy-recommendation and implementation, the following additional comments and recommendations are offered.

The societal and economic imperatives in Peru make it essential that development efforts be both efficient and productive. In view of this and at the risk of repeating what some may say are simply basic operational principles, it is suggested that:

1. In respect to new directions, it would be well to start modestly, learning as you go and building as experience and insight accumulates and as project success forms a sound base from which increased efforts can be launched with reasonable confidence and support.
2. To conserve funds and time maximum use should be made of those qualified people and facilities which are already available, although this may call for certain "sorting out" and reorganization measures.
3. High quality manpower is fundamental to the vital development targets emerging from the assessment program. By staffing the organization with the most competent personnel, program results can be optimized by drawing on their judgment and ability for accomplishment while the number of personnel can be minimized.

Present information suggests that the government may currently be experiencing difficulties in securing and holding such personnel. If this is true, then it is advisable to evaluate and introduce means (salaries, fringes, working environment) for overcoming the problem. In Korea the same need for high quality of personnel in the new developments existed. The Koreans were unable to attract the necessary people under their current civil service structure. They therefore set up a separate semi-autonomous structure with wages and fringe benefits sufficient to attract the people they needed. This approach was successful. Other countries have found similar actions necessary (see, for example, the Science and Technology Foundation (CIENTEC), Rio Grande do Sul, Brasil).

4. Manpower can also be optimized through the use of "qualified" external and internal training programs and by drawing on qualified manpower external to the basic "institution" (for example, private industry, consulting firms, various foreign assistance groups, non-profit development laboratories, etc.). Such external assistance, however, while augmenting a central planning and implementation core cannot substitute for that core.
5. The use of relevant experience external to Peru should be pursued. This is especially true in respect to rural projects where considerable experience is already available in respect to such approaches as improved solar drying of crops, low cost, reliable water pumps for villages, and small-scale hydropower plants.
6. It will be necessary to follow a strategic priority system in respect to projects. Those projects having the greatest near-term impact will undoubtedly dominate the initial development period even though a modest start on key mid-term projects may also be necessary in view of the time factor.
7. Project appraisals and ratings must be realistic in terms of funds, time and manpower required and potential pay-out.
8. Special care must be taken to ensure that an efficient "delivery system" is used. Disjointed and socially inept delivery systems have defeated many worthwhile projects. Social factors (implementation methods) can often be more important than the technology delivery even though the latter may be highly important in itself. Those who have worked with developments in the rural area are especially conscious of these factors.

It is to be noted also that the "delivery system" can vary with each project.

9. Innovation in project delivery can be of substantial value. Such value was shown in the rural village water pump installations in Costa Rica where these installations were made into communication centers.

10. The "production" or operating people who will be responsible for the "delivery" of the project must be included in the analysis and planning stage if their understanding, insight and full cooperation in delivery is to be had.
11. The recipient of the project must want the project or, as a minimum, be able to see its potential value to him. Force-feeding developments has a poor record of success.
12. Projects must have sound social, economic, and technical balance. Thus, it is necessary that the planning and policy-making "institution" have within itself the personnel who can comprehend and balance all three factors.
13. Development projects in any country or industry can be easily suffocated by "red-tape". It is one of their most virile enemies. Therefore, serious efforts must be made to minimize this problem.
14. Demonstrations are a key, necessary element in delivery system. Therefore, it is important to have available proper facilities for fabricating prototypes and pilot systems.
15. In view of the importance of the project delivery system, it is important to think through and spell out the delivery system for each project during its formative stages.
16. Manpower must be selected on the basis of "applications" ability. The projects are not research projects (the results of which can be better obtained from others at this stage in the country's development) but they are projects aimed at practical results in the field. Some would say, "you are looking for the 'doers'."
17. Project build-up and selection of project personnel will come after the planning stage so that projects have their proper place in the overall strategy and so that the personnel are matched to the task.

Additional Comments are:

If the "institution" is to be within the government, it may be well to consider a strong advisory board to provide high-level, outside expertise, independent appraisals (including constructive criticisms), a bridge to non-governmental institutions, etc.

Evaluation can be made of the potential assistance from groups external to Peru such as the O.A.S., regional laboratories, laboratories in Mexico, the U.S., Central America, etc., foreign industrial firms, etc. Plans and methods for utilizing these aids to the "institution" goals can then be formulated.

The government cannot do everything. Therefore, all useful elements outside the government must be drawn into the planning and implementation elements (i.e., industry, commerce, etc.). The United States tried to develop weapons entirely within the government at one time which led to the formation of the "Arsenals". These have turned out to be at best only a modest part of the desired weapons development and in some cases, more of a hindrance than a help.

It is suggested that evaluation be made of the extent to which industry can help with the energy development projects and plans be made to make maximum use of industry's capabilities. This can save in the search for experience, for personnel and for funds as well as providing a potential improvement in delivery system effectiveness.

With the exception of hydroelectricity, the renewable resources are not likely to make a very significant difference in the energy output of Peru in the near term and would be expected to make only a modest increase in the mid-term. However, in the sense of a total strategy their near term value has its greatest potential in reducing the rural problems in respect to drinking water, health and nutrition and in providing a possible base for improvement in agriculture and "cottage industries".

Development programs which will come from the policy-making and planning efforts will not usually be successful unless proper continuity can be provided. This is a difficult problem everywhere, for few countries and organizations can assure the 10 or 15 years of consistent effort often needed to see a project through to broad success. Nevertheless, thought should be given to this problem and possible methods for minimizing it, for it can often be more harmful to abandon a potentially successful project part way through than to have never started it. Thus, continuity provisions become a necessary function of the "institution" considered.

The studies, information and suggestions developed for this report during its brief time period have pointed up questions which need further evaluation. Some of these are discussed above in this section. Others include:

Comparison of the various statements with first-hand observation of the problems and situations in Peru.

Evaluation of present pertinent Peruvian organizations on the basis of quality, manpower and potential for productivity in contribution to energy program needs. Included would be estimates of modifications to such organizations which could improve efficiency and strength, reduce costs, etc.

Evaluation of the present degree of coordination of energy plans and projects and methods for improving coordination with present organizational structures.

Evaluation of facilities for "project delivery systems" including pilot plants, prototype fabrication shops, field facilities, etc.

Manpower evaluation from the viewpoint of the functions required of the "institution". Where are the most competent people? How good are they? Are there shortages? Where do you obtain others needed?

There appears to be a real need to review technical organizations, requirements and capabilities. There will most certainly be a need for a strong technical capability especially in the sense of "applied technology". However, in the effort to hold down expenses, there may well be a tendency to reduce the technology component to a small number of experienced engineers to handle immediate applications. This approach can result in narrow technical vision and no means for developing the new capabilities which will be required tomorrow. Thus, it is advisable to consider carefully the proper size and scope of the applied technology team and the means for maintaining the virility of that team including tie-in with university programs and time and means for the vital information exchanges with other technical groups in other countries. At the same time Peru does not now need a strong "research" capability and may have more technical teams than are actually needed.

Finally:

Deeper appraisal of the functional and organizational elements set forth in this report is suggested, especially in

respect to the question concerning a government-based "institution" versus a separate, essentially private "institution." There are real questions involved here including critical elements such as manpower, funding and implementation potential, all revolving around the need to select that approach which can best "get the job done" and can provide continuity under approaching political changes.

Appendices

Appendices

- A. "Current Energy Plans and Policies in Peru"
by Hermann Montalvan
- B. Peru: Institutional Organization Related
to Research, Science and Technology
- C. Charter for an Energy "Authority"
- D. Institute for Developing Energy Alternatives
- E. Peru; Average Wages
for Engineers
- F. The Program Management Function
- G. Organizational Arrangements for Implementing
Technology Transfer in Developing
Countries
- H. Examples of Industrial Research Institutes
in Developing Countries
- I. An Industrial Energy
Conservation Program Matrix
- J. Conferees
- K. References

Appendix A

Current Energy Plans and Policies
in Peru

by Hermann Montalvan
Director, Energy Planning Office
Ministry of Energy and Mines
Peru

II. ENERGY RELATED INFORMATION

A. ENERGY PLANS AND POLICIES

The following is an excerpt from a working paper ("Energy Sector in Peru: Actual Situation and Perspectives") prepared by Hermann Montalvan, Director, Energy Planning Office, Ministry of Energy and Mines, Lima, Peru. The views expressed by Mr. Montalvan are his own and do not necessarily reflect those of the Government of Peru.

Energy Planning Methodologies and Strategies

National energy plans have been formulated as part of National Development Plans, and have aimed at achieving the opportune and guaranteed satisfaction of the demand for energy that is required for national development.

Since 1970, there have been the 1971-1975 Quinquennial Plan and the 1971-1972, 1975-1976, and 1977-1978 biennial plans. The formulation of these plans has followed the directives given by the Instituto Nacional de Planificacion. Within the energy sector, the Oficina Sectorial de Planificacion is in charge of conducting and coordinating the process of formulation of the energy sector plans, which are elaborated with the participation of all institutions related to the energy sector.

The energy plans have defined the basic orientations for the development of the hydrocarbons and electricity sub-sectors, conceived as independent. In the long term energy plan, in actual preparation, all energy resources are taken together as a basic ground for national economic development. With this objective in mind, the plan is being formulated with the following basic criteria:

- o The plan horizon will be the year 1990, but it will include perspectives up to the year 2000.
- o The goal is to satisfy the energy requirements for national development, making rational and economical use of available energy sources, reducing dependency on foreign energy supplies as much as possible, and gradually matching the energy production and consumption structures in order to use the country's productive capacity in the most suitable way. In order to achieve this goal, the following is proposed:
 - o To intensify exploration activities in the coastal offshore and Amazonian regions, as well as the secondary recovery operations in the North-West, in order to increase the proved reserves of petroleum and natural gas.

- o To intensify the exploitation of the country's hydroelectric potential, aimed at substituting petroleum used for electricity generation. The systematic evaluation of hydropower potential and the implementation of important hydroelectric projects will be continued.
- o To increase the use of coal for electricity production, as an input into metallurgy and as a substitute for petroleum. For these reasons, the country's coal potential must be systematically evaluated and the Alto Chicama and Oyon development projects must be continued.
- o To promote the development of alternative energy sources such as nuclear and geothermal energy, in the first place, but also solar, wind and other nonconventional energy sources, to be used for generating electricity and heat.
- o To influence the energy consumption pattern and promote energy savings in order to use it more efficiently.
- o To promote greater integration of regional electrical systems, aimed at establishing a national interconnected system in the future.
- o To insure the availability of the economic and financial resources needed for the fulfillment of the long term energy development plan.
- o To increase the energy sector's technological level and to promote the professional capacity oriented toward energy projects, in order to be able to use, adapt, and generate technology efficiently.
- o To optimize the Government's managerial capacity for the development and operation of the energy sector, and at the same time, promote the administrative decentralization and deconcentration.

Criteria for Investment Allocation in the Energy Sector

In order to allocate investments in the energy sector, the following criteria are used:

- o The growth of the energy sector must be permanent and self-sufficient.

- o In scheduling energy supplies to the different sectors of the economy, priority is given to the productive sectors.
- o When the development of energy resources is considered, priority is given to the renewable resources.
- o Those energy projects, that require large investments which are beyond the financial capabilities of the sector, have to justify the central Government's assistance to the sector.
- o Promotion of regional development.

Selection of Energy Supply Alternatives

The process of selecting energy supply alternatives has so far covered only hydrocarbons and hydroelectricity. Other energy resources have not been considered but they will be taken into consideration for future energy supply alternatives.

The decision to choose a particular energy supply alternative is made after a process that includes pre-investment studies (preliminary, pre-feasibility, and feasibility studies), in which the technical, economic and financial characteristics are defined. Having the feasibility studies of the different alternatives as a frame of reference, those alternatives that offer the greatest advantages, in terms of the use of the capital, the return on the investment, social improvements, the use of indigenous resources, etc., are chosen.

For electricity planning, mathematical models have been used for some time to define the optimal strategy for supply of electricity. Also an optimization type macro model, which uses linear programming, is being implemented. It will yield the optimal supply alternative with the minimum social cost, considering the various constraints on the energy, economic, financial and other resources.

It should also be mentioned, that future electricity developments will be guided by the results of the National Energy Balances exercise.

Plan Implementation and Envisaged Problems

The implementation of the plan is the responsibility of the different institutions dealing with energy. Thus, for example, projects in the hydrocarbons sector are executed by PETROPERU, and those in electricity by ELECTROPERU and all the other public electricity enterprises.

The implementation of the plan's goals is periodically evaluated, and corrections are introduced as needed.

The problems that have hindered the fulfillment of the estimated goals for energy development are:

- o Insufficient organizational capacity of the executing agencies.
- o Scarce financial resources.
- o Lack of technical teams.
- o Inadequate information system.

Estimates of Future Requirements

To estimate the future energy demand, two methods have been used:

- Macro analysis, using correlations with Gross National Product and extrapolating historical series.
- Sectorial analysis, integrating the estimations made by different economic sectors.

The above methodology has been used to forecast demand for electricity and for petroleum and products.

The total primary and secondary energy consumption projections are presently being done within the framework of the national energy balances. These are currently being prepared, and the results are expected in the next few months.

In Table I it is shown that primary energy consumption, as well as electricity production, are expected to increase. These estimates have been based on the assumption that the gross national product will grow at a constant rate of 6.0% per year.

TABLE I

PROJECTIONS OF PRIMARY ENERGY CONSUMPTION AND
ELECTRICITY PRODUCTION (*)

YEAR	PRIMARY ENERGY CONSUMPTION (Tcal)	ELECTRICITY PRODUCTION (Gwh)
1976	83,968	7,767
1977	89,721	8,225
1978	95,020	8,770
1979	100,631	9,515
1980	106,574	10,170
1981	112,868	10,870
1982	119,534	11,618
1983	126,593	12,418
1984	134,069	13,273
1985	141,987	14,187

(*) The following correlation equations were used:

Primary Energy: $EP = 0.68773 (GNP)^{0.98472}$

Electrical Energy: $EE = 0.00964 (GNP)^{1.14276}$

Possibilities and Limitations of Inter-Energy Substitution

As already mentioned, some steps have been taken to substitute petroleum generated thermal electricity with hydropower. It is expected that starting in 1978, 300 Gwh of thermal electricity will be substituted; this will amount to 540,000 barrels of petroleum per year.

In order to study the rational use of energy, examine the energy savings possibilities and evaluate the alternatives to petroleum, the National Energy Balances are presently being prepared and the results will be known in the next few months.

Some of the substitution possibilities considered for the near future are the following:

- o Substitution of petroleum generated thermal electricity with hydroelectricity from large hydroelectric plants that are presently being built or are being planned.

- o Electrification of mass urban and suburban transportation.
- o Use of coal for generating electrical energy.
- o Substitution of petroleum with other energy sources in industrial processes.

Supply Situation

The present and future situation in the supply of energy needed for the country's economic development is as follows:

1. Petroleum

By 1978, Peru will become self-sufficient in petroleum. However, based on the known proved reserves, this situation will last only until 1983. In the meantime, the energy and mining sector is promoting an integral energy policy that includes an increase in petroleum production and a decrease in the share of hydrocarbons in total energy consumption. Production, consumption as well as trade in hydrocarbons are shown in Table II.

TABLE II
PRODUCTION, CONSUMPTION AND TRADE
IN HYDROCARBONS

(THOUSAND B/D)

YEAR	PRODUCTION	CONSUMPTION	(IMPORTS) EXPORTS
1976	76.4	124.5	(48.1)
1977	99.5	121.0	(21.5)
1978	146.1	129.0	17.0
1979	177.3	137.0	40.0
1980	181.7	145.0	36.7
1981	184.6	151.3	33.3
1982	179.4	160.0	19.4
1983	173.1	170.0	3.1
1984	166.7	180.0	(13.3)
1985	159.7	193.1	(33.2)

The projects that will allow the country to become self-sufficient in petroleum are the following:

- North Peruvian pipeline, already in operation.
- Northern branch pipeline, under construction.
It is expected to be completed in 1978.
- Petroleum exploration programmes in the Amazonian region and in the country's North-West.
- Secondary recovery programme in the country's North-Western region.
- Increase in the country's petroleum refining capacity in order to satisfy growing domestic demand and eliminate imports of petroleum products. This will be achieved with the 65,000 B/D capacity expansion of the La Pampilla refinery, with a new unit for primary distillation.

2. Electricity

Demand for electricity is expected to increase in the future, since at present only a little more than 30% of the country's population is supplied with electricity.

Also, because some energy projects were not in operation at their expected dates, the electricity supply in some electrical systems is restricted. This is the case in Arequipa, Chiclayo, Piura, and others. In these places, the situation is being alleviated with emergency thermal units.

To overcome this situation, an equipment programme has been designed which includes projects under construction and studies at different levels of development. Implementation of this programme, which emphasizes the development of hydroelectricity, will result in meeting of the country's electrical energy needs for the next few years. Table III lists those projects which are expected to be completed in the next few years.

It is in this sense that the construction of the 425 Km 220 KV Lima-Chimbote transmission line and the interconnection between the CENTROMIN-PERU system and the Mantaro hydroelectric plant are being implemented. These projects, when completed in 1980, will form the Central-Northern interconnected system with an initial capacity of more than 1,800 MW and with an area of distribution that will cover Departamentos of La Libertad, Ancash, Lima, Huanuco, Pasco, Junin, Ica and Huancavelica. At the same time, the completion of the 220 KV transmission line from Toquepala to Arequipa will form the Southern Interconnected system, with an initial installed capacity of more than 220 MW and an impact on an area that covers Departamentos of Arequipa, Moquegua and Tacna.

Supplying other areas will be done from isolated electrical systems.

TABLE III
PRINCIPAL HYDRO AND THERMAL PROJECTS

Project	Type (X)	CAPACITY (MW)			EXPECTED COMMISSION- ING DATE
		Present Installed Capacity	Increment	Final Installed Capacity	
Antaro	H	342 (1)	458 (2)	798	1979/1980
. del Pato	H	100 (1)	50 (2)	150	1979
achu P.	H	40 (1)	70 (3)	110	1982
harcani	H	135 (3)	—	135	1982
quitos	T	10 (2)	10	20	1980
ucallpa	T	10 (2)	10	20	1982
estituc	H	217 (3)	—	217	1982
egue	H	300	300	600	(4)
aucartan	H	111	—	111	(4)
l. Chicam	T	160	320	480	(4)
lmos	H	150	220	370	(4)
ajes	H	136	520	656	(4)
arhuaq.	H	75	—	75	(4)
l Chorro.	H	150	—	150	(4)

(X) H Hydro

T Thermal

(1) Operational

(2) Under construction

(3) Financial agreements

(4) To be commissioned after 1983

The equipment programme shown in Table 12 responds to the Government's policy of using hydro-power potential for electricity generation, as well as setting of a centralized supply through interconnected electrical systems.

Special Aspects

1. Cooperation at Subregional and Regional Levels

Peru is promoting cooperation in energy development at the subregional as well as the Latin American levels. In this sense, it participates and proposes actions in the Grupo Andino, OLADE and ARPEL.

At present, Peru and Ecuador are executing feasibility studies for the Puyango-Tumbes multi-purpose project. Great importance is also being attached to joint studies on exploration and utilization of non-conventional energy resources, such as nuclear, geothermal, solar, etc. Furthermore, the exchange of experiences with other countries on energy balances elaborations and energy planning is considered useful.

2. Energy Conservation and Measures to Reduce Consumption

No energy conservation measures have been implemented mainly because the country does not waste any energy. However, with regard to energy savings, some measures have been proposed for the future and will be finalized when the results of the National Energy Balances are known.

SECTION XII.

Appendix B

Institutional Organization

in Peru

Related to Research, Science and Technology

P E R U

INSTITUTIONAL ORGANIZATION RELATED TO RESEARCH, SCIENCE AND TECHNOLOGY

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PERU: INSTITUTIONAL ORGANIZATION RELATED TO RESEARCH, SCIENCE AND TECHNOLOGY

I. Background Information

Until the mid-sixties, the science and technology research activities in specific fields developed without any institutional regulation. The principal organizations were the universities and the Geophysic Institute.

In 1965 the armed forces established an office for research and development in defense technology. This was expanded in 1968 to the national level through the Asociacion Peruana for the Advancement of Science and the Consejo Nacional de Investigaciones.

It was to be the function of the Consejo to promote research in the various scientific fields. An ambitious program was prepared but the Consejo was never funded nor were its by-laws established.

At the beginning of the "seventies" the need for organized promotion of research activities was recognized and new policies for research and for the advancement of science and technology were established. A number of institutions were created within a national system including the operating ministries. These institutions are as follows:

- A. At the Office of the President: CONI, INP and ONERN (see accompanying list of acronyms).
- B. At the Ministry of Industry and Tourism: ITINTEC.
- C. At the Ministry of Energy and Mines (MEM): INCITEMI, INIE, INGEOMIN and IPEN.
- D. At the Ministry of Alimentacion (Food), the Direccion General de Investigaciones (Research), CRIA and IIA.
- E. At the Ministry of Pesqueria (Fishing): IMARPE and the Direccion General de Investigaciones Pesqueras (Fishing Research).
- F. At the Ministry of Education: INIDE, the Instituto Geofisico del Peru, the Universities, ESEP and INAE.
- G. At the Ministry of Transport: INICTEL.
- H. At the Ministry of Defense, the Ministry of Health, the Ministry of Housing, specialized divisions are established.

Each of the agencies listed are chartered for specific tasks, and are to be coordinated within the national "economic and development plan" by the Instituto Nacional de Planificacion (INP).

ACRONYMS

CRIA:	Centro de Investigaciones Agropecuarias (Center for Agriculture and Cattle Research)
CONI:	Consejo Nacional de Investigaciones Cientifico y Tecnológico (National Council for Science and Technology Research)
CONITE:	Comision Nacional de Tecnología Extranjera (National Commission of Foreign Technology)
ELECTROPERU:	Servicios Electricos del Peru
ESAN:	Escuela Superior de Administracion Nacional (School of Higher Public Administration)
ESEP:	Escuela Superior de Educacion Profesional (School of Higher Professional Education)
IIA:	Instituto de Investigaciones Agro-Industriales (Research Institute for Agriculture and Cattle)
IMARPE	Instituto Marítimo Peruano (Peruvian Marine Institute)
INAE:	Instituto de Altos Estudios (Institute of Higher Studies)
INDIPRO:	Instituto para el Desarrollo Industrial y Profesional (Institute for Professional and Industrial Development)
INICTEL:	Instituto Nacional de Investigaciones y Capacitacion de Telecomunicaciones
INCETEMI:	Instituto Cientifico y Tecnológico Minero (Mining Science and Technology Institute)
INIE:	Instituto de Investigaciones Energeticas y Servicios de Energia (Research Institute on Energy and Energy Services)
IPEN:	Instituto Peruano de Energia Nuclear (Peruvian Institute for Nuclear Energy)
INGEOMIN:	Instituto de Geologia y Minas (Geology and Mining Institute)
INP:	Instituto Nacional de Planificacion (National Planning Institute)
ITINTEC:	Instituto de Investigaciones Tecnológica Industrial y Normas Tecnicas (Institute for Industrial Technology and Technical Standards)
MEM:	Ministerio de Energia y Minas (Ministry of Energy and Mines)

METIC: Ministerio de Industria, Turismo y Comercio
(Ministry of Industry, Tourism and Commerce)

OEA/OAS: Organizacion de los Estados Americanos
(Organization of American States)

ONERN: Oficina Nacional de Evaluacion de Recursos Naturales
(Office for the Evaluation of Natural Resources)

PETROPERU: Petroleos del Peru

SENATI: Servicio Nacional de Aprendizaje y Trabajo Industrial
(National Service of Training and Industrial Works)

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INSTITUTIONS AFFECTING TRANSFER OF TECHNOLOGY

II. STRUCTURE OF THE INSTITUTIONAL SYSTEM FOR THE PROMOTION OF SCIENCE AND TECHNOLOGY IN PERU *

The basic structure is divided into two levels: organizations at the national and at the sectorial level.

A. Organizations at the national level:

1. Instituto Nacional de Planificacion (INP), with responsibility for the overall social and economical development planning.
2. Consejo Nacional de Investigaciones (National Research Council), which is responsible for specific science and technology policies and for the coordination of technical institution activities.
3. Comision de Ciencia y Tecnologia

B. Organizations at the sectorial level:

1. Organizations related to specific ministries with administrative and economic autonomy: ITINTEC, INIE, INCITEMI, IMARPE, (IPEN, INICTEL, IGP, INGEOMIN, ONERN, INIDE, PETROPERU, ELECTROPERU)
2. Organizations administratively and economically directly dependent on their respective ministries:
 - a. The Direccion General de Investigacion of the Food Ministry.
 - b. The Direccion General de Investigacion of the Fishing Ministry.
 - c. The Direccion General de Investigacion of the Transport Ministry.
 - d. The Direccion General de Investigacion of the Agriculture Ministry.
 - e. Instituto de Investigaciones azucareras (from the Ministry of Agriculture).
 - f. Universities (Ministry of Education).
 - g. Comision Nacional de Investigaciones, Tecnologia Extranjera (of the Ministry of Economy and Finance).
 - h. Servicio Nacional de Metereologia e Hidrografia.

C. Private organizations:

1. ESAN, Escuela Superior de Administracion Nacional
2. ESEP, Escuela Superior de Educacion Profesional
3. INAE, Instituto de Altos Estudios
4. Universities (11).

*Data from OAS, Unidad de Planificacion; Estructura del Sistema Cientifico y Tecnologico del Peru. Junio 1976.

Table I: Budgets for Science and Technology Related Organizations
(in thousand of Soles)

Organization	Sector	Budget 1975-76	Budget 1977
Desarrollo científico y tecnológico - CONI	Office of the President	19,951	10,800
ONERN	Office of the President	65,050	57,300
Investigación Científica y Tecnológica	Min. Fishing	32,356	8,495
IMARPE	Min. Fishing	196,400	249,600
Instituto de Investigación Agro-Industrial	Min. of Food	105,022	98,000
Dirección General de Investigación Agro-pecuaria	Min. of Food	23,291	30,232
IPEN - Junta de Control de Energía Atómica	Min. of Energy & Mines	44,600	64,700
INCITEM	Min. of Energy & Mines	433,226	175,298
INGEOMIN - Servicio de Geología y Minas	Min. of Energy & Mines	93,619	57,964
INICTEL	Min. of Transport & Comm.	42,800	14,300
Instituto Geofísico del Perú	Min. Education	70,612	95,000
Institutos Nacionales de Salud	Min. Health	475,406	271,300
Oficina de Investigación y Formalización	Min. Housing	10,155	10,000
ITINTEC	Min. of Industry	266,384	270,877
TOTAL		1,878,872	1,423,866

III. PRINCIPAL ORGANIZATIONS AFFECTING RESEARCH AND DEVELOPMENT

Brief description:

A. On the National Level:

1. Instituto Nacional de Planificacion (INP)

Objective: to formulate and coordinate the national development plan, setting forth the financial needs and budget assignments.

Within its functions is included the assignment of funds to the science and technology research organizations through the Comision de Ciencias y Tecnologia whose board includes representatives from the ministries as well as from the autonomous organizations related to the technical fields.

The INP reports directly to the Office of the President.

2. Consejo Nacional de Investigaciones (CONI)

CONI was established by decree in 1968, reporting also directly to the Office of the President.

Objective: to promote, coordinate and guide scientific and technology research in Peru.

The functions include policy formulation and advisory services to the Office of the President in all aspects relating to these fields. CONI was expected to coordinate the activities of the specialized research centers and to act as intermediary before international organizations, such as the OAS and UNESCO.

As the Consejo has not been established through necessary by-laws and has not been funded, it remains inoperative.

B. On the Sectorial Level:

Following the specific needs and requirements of the productive sector, a number of institutions were created:

1. Nuclear energy.

IPEN (Instituto Peruano de Energia Nuclear), in charge of the promotion, coordination and control of the use of nuclear energy.

2. Electric power.

The coordination in this field is provided by the Ministry of Energy and Mines through two dependent agencies acting under one common chairman designated by the Ministry.

a. INIE (Instituto Nacional de Investigaciones Electricas y Energeticas.) Its primary function is to prepare studies on electrical power development and power plants.

b. ELECTROPERU. This organization operates all power generation and distribution in the public sector, sets the plans and expansion programs, and coordinates all installations. It has received technical assistance from Electrowatt (Swiss Co.) and has formed with the assistance of the German Government a study group named ODEPA (Organizacion de Desarrollo Energetico Peruano Aleman) which prepared studies on overall power requirements.

3. Telecommunications.

INICTEL (Instituto Nacional de Investigaciones y Capacitacion de Telecomunicaciones) supervises all aspects related to the development of telecommunications, including the training of specialized personnel.

4. Industrial Sector.

a. ITINTEC (Instituto de Investigaciones Tecnologica Industrial y de Normas Tecnicas) was established by decree in 1970 as an administrative and economically autonomous agency within the Ministry of Industry.

Objectives: to promote, coordinate and guide science and technological research related to industrial development; to prepare and set quality standards, to improve industrial production standards, providing quality control and seals of approvals; to provide information related to industrial technology.

ITINTEC's principal functions are:

- a. Research
- b. The preparation of standards and norms
- c. Technical information in the industrial field.

ITINTEC is also supposed to participate in the training of technical personnel for research and to act as the intermediary responsible agency for the coordination of activities in the technical field emanating from the Cartagena Agreement on transfer of technology (Decision 24 and Decision 84) by decree of June 1975.

Administrative structure: *

The organization is headed by a "Director General" who reports to the "Consejo Directivo" (Board) which is made up of a president and three representatives, one from the Ministry of Industry, one from CONI and one from INAE (Institute de Altos Estudios).

The staff functions are managed by four divisions: 1. Administration; 2. Legal; 3. Public relations; 4. Information and documentation. The operative functions are executed by the Division de Normas and the Division of Industrial Technology.

*From OAS report previously listed.

Financial resources:

By law ITINTEC receives 2% of net earnings from all medium and large industrial enterprises (manufacturing). These are defined as those where net sales are more than 590 yearly salaries paid for labour. In July 1978, this represented an equivalent to US \$259,000.

However, these funds are only to be paid by those enterprises which do not use the funds to perform research at their own installations or by direct subcontract to other technical organizations.

Alternatively, an enterprise can request that ITINTEC carry out research in specific fields related to the particular interests of the enterprise using the "2%" funds. ITINTEC may do the research at its own facilities or may subcontract for it with other institutions as advisable.

ITINTEC has planned the establishment of specific research facilities in the following fields:

- a. Automotive industry
- b. Non metal minerals utilization
- c. Woodworking industry
- d. Electronic industry
- e. Library and information center.

The information center and the electronic laboratory are operative. The woodworking center is next in line.

It is the intention of ITINTEC to provide in these research centers specialized assistance to the government and to industry, to improve materials utilization and improve the quality of production providing quality certification on request.

The section dedicated to setting standards or norms has produced several publications.

Performance: During seven years of operation up to December 1977, 585 projects had been submitted to ITINTEC. Of these 330 received approvals, 41 were taken back by the originators, 210 were rejected, and 4 remain under evaluation.

In June 1978, ITINTEC had a staff of 86 persons of which 57 were professional degree holders and 12 were technicians.

The 330 approved projects, represented a total value of S/.585 million (\$3.4 million) distributed over the following fields:

Table II
APPROVED RESEARCH PROJECTS *

Sector	No. of Projects No.	Value in Thousands of Soles	% of Total %
Food, beverage, tobacco	74	157,815	24
Rubber, leather, paper	35	67,405	10
Pharmaceutical, cosmetics	8	6,831	.2
Wood, Cellulose products	15	43,744	.6
Electric Machine and Equipment	34	40,558	4
Metal mechanics	43	94,408	23
Chemicals	54	87,221	18
Minerals non metal	34	44,688	9
Textile	28	53,850	11
Not specified	5	2,067	.2
TOTAL	330	598,587	100

*Data provided by ITINTEC

b. SENATI (Servicio Nacional de Aprendizaje y Trabajo Industrial)

SENATI is a decentralized public organization devoted to training and development of skilled workers, technicians and lower and middle level managers in the industrial sector. It also operates facilities for the production of prototypes. It is directed by its National Council composed of three representatives from the Ministry of Industries and Tourism (One of whom acts as chairman), and one representative each from the Ministry of Education, Ministry of Labour and the National Planning Institute.

It is financed through a 1.5% levy on the salaries paid by all enterprises with over 15 workers. This levy is called the "contribution for Science and Technology". The UNDP (United Nations Development Programme), the ILO (International Labor Organization) and technical assistance organizations of various countries, including the Federal Republic of Germany, United Kingdom, France, Belgium, Austria, Netherlands and Japan, have been extending support to SENATI in the development and implementation of its programs.

The organization has approximately 900 professional and semi-professional staff distributed between its head office in Lima and two regional offices in Chiclayo and Arequipa. While its main area of activities has been vocational

training in diverse fields within the industrial sector, this assignment in the near future may be extended to the management level and to industrial product development activities. Presently SENATI offers 2-3 year apprenticeship programs to young secondary school students, evening courses to adults and on-the-job training programs for workers already employed. It has special 9 month, twice-a-week evening training courses for specialized workers in industry.

SENATI's present management training programs are varied in content and duration. They include courses in administration, production, basic accounting and finance and appear to be generally oriented towards shop floor supervisors and lower level managers. All of SENATI's programs are free to the participants since SENATI receives its funds directly from the Government. To improve assistance to regional industries in the country, SENATI operates 8 mobile units for vocational training.

In 1973 with the collaboration of the Federal Republic of Germany, SENATI started a program called INDIPRO (Instituto para el Desarrollo Industrial y Profesional). Through this program it seeks to provide analytical services and assistance in technical and administrative matters to small enterprises located in the Lima area.

Mining sector:

INCITEMI (Instituto Cientifico y Tecnologico Minero) is responsible for research and development in the mining field. It was established in June 1971 as an administratively autonomous organization functionally under the Ministry of Energy and Mines.

Objectives: to promote, coordinate, guide and execute all research projects relating to mining activities, as well as to advise the Ministry of Energy and Mining and to set standards in coordination with ITINTEC.

The Institute's functions include policy-setting for the Ministry in respect to Research and Development activities and the promotion of training for professional personnel.

Administrative structure:

INCITEMI is administered by the "Consejo Administrativo" consisting of: a President and three representatives from the Ministry of Energy and Mining and one representative each from the Ministry of Industry and Tourism, the Mining Enterprises (CENTROMIN), the University system and CONI.

Chief executive of INCITEMI is the Director General. He has the following departments: Administration, Legal, Public Relations, Planning and an operational department divided into two parts, research and development, and the "projects of the South".

Finance:

INCITEMI receives 1% of the net earnings of all mining enterprises*, as well as funds from the Ministry's budget, from participation in the sales of minerals and government mining property, and from contributions from international and private organizations.

Activities*: The following projects were identified in the program for 1975/76: Evaluation of resources on the continental shelf; studies to improve productivity in the mining sector; study of the mechanical properties of rocks and stones; study of hydraulic fillings; systematization of metallurgical controls; study to eliminate the arsenic content in copper concentrates; study of open pit mining technology; study of the metallurgy of non-ferrous metals; study of the hydrometallurgy of copper; inventory of mining potentials; and standardization of production.

Food sector:*

Research and development activities in the food sector and their coordination with specialized agencies, public or private are under the supervision of the Ministry of Alimentacion (Food) through the Direccion General de Investigaciones Agro-Industriales.

Fishing sector:*

Research and development activities in this field are under the control of the Ministry of Fishing's Instituto del Mar Peruano (IMARPE) through the Direccion General de Investigaciones Cientificas y Tecnologicas at the Ministry.

Foreign related activities:*

In May 1976 a special commission CONITE (Comision Nacional de Inversiones Extranjeras) was established to propose policies for the treatment of investments in foreign technologies in compliance with objectives established by the Cartagena Agreement.

The Commission consists of three representatives from the Ministry of Finance, two from the Ministry of Industry and one from the Ministry of Energy and Mining. It reports to the Minister of Finance.

Education Sector:

Higher education activities are regulated by the National Education Law. Three basic education levels have been established:

- a. The Escuela Superior de Educacion Profesional (ESEP):
for vocational training, teachers colleges and
technical training institutes.

*Data provided by the OAS.

- b. The Universities for higher academic training.
- c. INAE (Instituto Nacional de Altos Estudios) dedicated to research and academic scientific education.

The plans for ESEP call for the establishment of 180 institutions by 1980 to serve 700,000 students. Currently there are 22 government-run universities and 11 private operated universities of which 5 are only in the humanities field.

The current university situation is rather chaotic. The number of student applicants increased from 14,000 in 1960 to over 110,000 in 1974. Of these, only 6,000 were accepted in 1960 and 38,000 in 1974. The funds available for education have not been increased in past years and therefore, the teaching body has thinned out. The proportion of teachers to students decreased from 1:8 in 1960 to less than 1:17 by 1974. Of these 1,500 were full time teachers and 4,700 were part-time.

Table III shows the number of Government Universities and the budget allocated for research activities.

TABLE III
GOVERNMENT UNIVERSITIES

University	Expenditures for Research in 1974
San Luis Gonzales	3,715,000
Amazonia	4,822,000
San Antonio de Abad	3,790,000
Piura	7,678,000
Universidad Nacional de Ingenier	5,648,000
Cajamarca	3,376,000
Huamanga	5,854,000
Ruiz Gallo	3,966,000
Altiplano	3,270,000
Villareal	7,383,000
Centro	5,175,000
Trujillo	5,010,000
San Agustin	16,680,000
Universidad Nacional Agraria	27,124,000
San Marcos	77,110,000
<hr/>	
TOTAL	180,601,000 Soles

Appendix C

Charter For
An Energy "Authority"

CHARTER FOR AN ENERGY AUTHORITY *

There is hereby established in the executive branch of the Government of a developing country an independent Authority to be known as the Energy Authority (hereinafter referred to as the Authority). The Authority shall consist of a National Energy Board together with its staff and a director (hereinafter referred to as the Board).

Functions of the Authority

- A. The Authority is authorized and directed:
 - 1. to form national energy plans, policies, and strategies derived from and consistent with national plans and policies;
 - 2. to implement approved national energy plans, policies, and strategies through:
 - a. applied technology studies and developments including demonstrations;
 - b. promulgation of appropriate economic and environmental protection regulations;
 - c. exploration for new energy resources;
 - d. financial implementation of new energy initiatives.
- B. The Authority is authorized to support those specific energy initiatives required to fulfill the national energy plan. Furthermore, the Authority, which has no facilities of its own for development and operations, is directed to carry out these initiatives by employing existing governmental, private and academic institutions.
- C. In exercising the authority in discharging the functions referred to in the foregoing subsections, it shall be the objective of the Authority to strengthen the overall energy position of the Nation through education and public awareness.

National Energy Board

- A. The Board shall consist of 10 members to be appointed by the Head of State. The membership shall consist of the Chairman, the Director of the Energy Authority (ex officio), the Minister for Energy and Mines, the

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*Elements from this Charter might also be used in the Charter for the Institute for Developing Energy Alternatives

Minister for Industry and Tourism, the Minister for Education, the Director of the National Planning Institute, and 4 additional members drawn from the private sector. In addition to any powers and functions otherwise granted to it by this charter, the Board shall establish the policies of the Authority within the framework of applicable policies as set forth by the Head of State and the Cabinet.

- B. The Chairman of the Board shall be appointed by the Head of State.

Director of the Energy Authority

- A. The Director of the Energy Authority shall be appointed by the Head of State. Before any person is appointed as Director, the Head of State shall afford the Board an opportunity to make recommendations to him with respect to such appointment.
- B. The Director in his capacity as an ex officio member of the Board shall coordinate with other members of the Board. He shall be a voting member and shall be eligible for appointment if the Head of State so desires as Chairman.

General Authority of the Energy Authority

The Authority shall have the authority within the limits of available appropriations to do all things necessary to carry out the provisions of this Charter including, but without being limited thereto, the authority

- A. to prescribe such rules and regulations as it deems necessary governing the manner of its operations and its organizations and personnel;
- B. to make such expenditures as may be necessary for administering the provisions of this Charter;
- C. to enter into contracts or other arrangements or modifications thereof for the carrying on of organizations or individuals in Peru and foreign countries including other government agencies of such activities as the Authority deems necessary to carry out the purpose of this Charter;
- D. to publish or arrange for publication of information so as to further the full dissemination of information about energy consistent with the national interest;

- F. to arrange with and reimburse the heads of other government agencies for the performance of any activity which the Authority is authorized to conduct.

Patent Rights

- A. Each contract or other arrangement executed pursuant to this charter which relates to energy development shall contain provisions concerning the disposition of inventions produced thereunder in a manner calculated to protect the public interest and the equities of the individual or organization with which the contract or other arrangement is executed. Provided, however, that nothing in the Charter shall be construed to authorize the Authority to enter into any contractual or other arrangement inconsistent with any provision of law affecting the issuance or use of patents.

International Cooperation and Coordination with Foreign Policy

- A. The Authority is hereby authorized to cooperate in any international activities consistent with the purposes of this Charter and to expend such sums within the limit of appropriated funds as the Authority may deem desirable.
- B. The Authority is authorized to enter into contracts or other arrangements with organizations or individuals in foreign countries and with agencies of foreign countries to the end that such authority shall be exercised in such manner as is consistent with the foreign policy objectives of Peru.
- C. If in the exercise of Item A above negotiations with foreign countries or agencies thereof becomes necessary, such negotiations shall be carried on by the Minister of Foreign Affairs in consultation with the Director.

Appropriations

- A. To enable the Authority to carry out its powers and duties, annual appropriations shall be made to the Authority in sums determined by the Head of State and the Cabinet.

Appendix D
Organizational Concepts
for an Institute for
Developing Energy
Alternatives
(Option 6)

Organization Chart

P = Planning element as defined previously

I = Implementation element as defined previously

EL = Energy laboratory to be specified in subsequent section

Board of Trustees

It is recommended that the Board be organized in a manner similar to that of the highly successful National Advisory Committee for Aeronautics in the United States. That is, there would be a parent board of about 15-20 members with a number of committees which aid the board in policy-making. The current National Science Board in the United States is similar to the NACA. In the non-profit area, the Aerospace Corporation and the MITRE Corp. are almost exactly analogous to the present proposal. Also the RAND Corporation and IDA have some similarity.

Chaired by member of the board with non-board member drawn from Peruvian & international financial community. Works primarily with the board in raising program money.

Chaired by members of the board with non-board members drawn from Peruvian and international energy planning community. Assists the board in specifying planning policy.

Chaired by members of the board with non-board members drawn from Peruvian and international energy technical community. Assists the board in specifying program policies. There may be several technical subcommittees; solar, hydropower, etc.

Energy Laboratory, [EL]

In addition to the planning element [P] and the implementation element I, introduced previously, the non-profit organization incorporates a new element [EL]. There is a very simple idea behind the need for [EL]. In order to make sound programmatic decisions, to select "best performers" and to provide hard nosed program management, there is required in the organization a high level of technical competence. Experience has shown that the best way to ensure that this technical competence is available is to carry on a certain amount of hands-on work in relevant fields. Thus, a laboratory [EL] that is carrying on some development work in such technical fields as materials, energy conversion, solar hot water and solar photovoltaics, hydropower, geothermal, etc., will ensure that technically qualified people are available to aid in judging proposals and make programmatic decisions. Indeed, the opportunity to take part in some hands-on development is often the best and only inducement for hiring and retaining highly qualified technical people. The criterion for operating [EL] should be that of doing

as much in-house development as necessary to ensure that a cadre of technically competent people is available to manage the program which is for the most part carried on by "best performers" on the outside. It must be emphasized that this is not a trivial recommendation since experience in the U.S. has shown that technical organizations engaged in program management rapidly became out-dated and ineffective unless some of the personnel is kept current by a "hands-on" laboratory such as EL .

In addition to EL , it is highly recommended that there be a significant number of "rotators" brought into the corporation from outside institutions like industry so as to constantly infuse up-to-date technical knowledge into the planning and program management.

Appendix E

Peru, Average Wages
for Engineers

8/30/78

ANNUAL COSTS FOR ENGINEERS IN PERU

Junior Engineer:

25 - 35,000 s/mth.

Total cost = above + 50%

Thus, total cost range = \$3000 - \$4100/yr.

Medium Engineer:

35 - 55,000 s/mth.

Total cost = above + 50%

Thus, total cost range = \$4100 - \$6500

Senior Engineer:

55,000 - 75,000 s/mth.

Total cost = above + 50%

Thus, total cost ranges = \$6500 - \$8900

Project Manager:

90 - 120,000 s/mth.

Total cost = above + 50%

Thus, total cost range = \$10,600 - \$14,000

Senior Manager:

150,000 s/mth.

Total cost = above + 50%

Thus, total cost = \$18,000/yr.

Via Gerardo Cahn-Hidolgo
8/30/78

Appendix F

The Program Management Function

The Program Management Function

The program management function is an important element of implementation in all of the options described in the previous sections. The program manager plays a key role in national programs. He must be distinguished from the project manager or project leader. Whereas the latter directs individual projects in the field, the former is responsible for national planning and programming, including the preparation of budgets, as well as overseeing, in a programmatic sense, all project managers in a given program. In the institutional options discussed above, program managers are an integral part of the implementation element, I, whereas project managers are, in general, located in operating units such as industry, universities, applied technology laboratories and other government ministries and agencies.

It is, for example, possible that a single program manager be assigned the field of solar energy in a developing country. He would thus be responsible for the planning, budgeting and implementation, including the mapping out of technology delivery systems, for all solar energy initiative. He would seek out and place under contracts, or suitable working agreements, those institutions in the country that promise to be the "best performers" of the various projects in the solar energy program. The selection of "best performers" would be made either by a sole source according to the judgment of the program manager or by competitive bidding. The program manager would continue to manage the new initiatives until such time as they reach maturity and the management is transferred permanently to an operating entity or industry or another ministry. The accompanying diagram illustrates a hypothetical range of responsibilities for the solar energy program manager.

Solar space and water heating, solar voltaic and wind energy initiatives would be distributed throughout the operating units such as industry, applied technology laboratories, universities and other government ministries and agencies. During the initiative phase, project managers in these operating units would receive their budgets and program direction from the program manager. As mentioned earlier, if the project shows promise of economic viability, and it is judged to be convertible into a permanent energy source, it would be detached from I and managed and budgeted entirely under an operating unit such as MEM.

One of the most important functions of a program manager in a national program such as solar energy is that of coordination. In most countries, the energy performers include institutions that are public, private or quasi public-private. The program manager must have full awareness of the totality of what these institutions are doing in his field. He achieves this awareness through outside advisory committees and other data-gathering systems that may be fitted to his particular situation. Having achieved this awareness, it is possible then for him to make judgments if government intervention is desirable and, if so, where and to what extent. It must be emphasized that the overall technical capability and knowledge of the program manager will be a key ingredient of success.

Since the program manager is in a unique position at the boundary between hardware development and operations, on the one hand, and the political leadership of the government, on the other, an experienced engineer or scientist is required. He should have had previous experience as a project manager with a proven record of hardware development and, at the same time, should be a competent planner and manager who understands the political, governmental and private environment in which he must function.

Engineers with the experience and ability to lead national programs as program managers are difficult to find, even in the advanced industrial countries. Although university education can provide the underlying knowledge in science, technology and management required for a program manager, an apprenticeship under an experienced program manager is also desirable. It is possible that in areas of program management new to a developing country, periods of apprenticeship could be provided to engineers by the energy agencies of other advanced countries. Conversely, experienced program managers could be loaned by advanced countries to developing countries for periods of one to two years to provide training or supervisory periods for apprentices.

Finally, it must be emphasized again that competent and experienced program managers are essential for success in national energy initiatives. A successful program manager must not only have high technical competence, but a full understanding of the political and social environment in which he works with the desire and ability to achieve results in the face of the bureaucratic road-blocks which are always present in government operations.

Appendix G

Organizational Arrangements
For Implementing
Technology Delivery
In Developing Countries

Organizational Arrangements for Implementing Technology Delivery In Developing Countries

The Industrial Research Institute (IRI) is an organizational arrangement that has been frequently used in the attempt to bring advanced technology to industries in developing countries (1) such as Brazil, Colombia, Venezuela, Guatemala, Korea, Nigeria, Indonesia, India, Pakistan, etc. It has taken many organizational forms (all of them non-profit in nature): government corporations, separately incorporated institutes, regional institutes, university applied research centers, government civil service institutes (state and federal), and research institute systems.

The ideal towards which these various forms of research institutes must strive is (2): "an autonomous multipurpose organization with techno-economic competence, deriving some funds from public sources for non-sustaining activities such as service to small enterprises, but rigorously oriented toward direct service to the industrial community." According to Blackledge (1) "with careful planning and expert leadership, the research institutes, as permanent institutions, can become valuable reservoirs of knowledge on the industrial problems specifically relating to the developing country's progress. They also become reservoirs of knowledge about technology from other countries, and with the appropriate mix of skilled and experienced staff members in many disciplines (scientific, technical, economic, administrative) can bring about effective exploitation and utilization of foreign technology." An industrial research institute in a developing country, in general, is expected to identify the technical problems of industries in the country (and agriculture too, for that matter) and the required technical knowledge available from advanced countries, and to match the two, doing adaptive research of its own if necessary to solve these problems. The IRI is also expected to find new products, processes and services that can help to expand existing businesses or create new ones. They should be able to help banks evaluate the merits of new technologies for which they expect to lend money to local businesses, and to help in the planning activities of the country's government which relate to new technological opportunities.

The industrial research institute is a convenient focal point for assistance by U.S. government agencies such as the Agency for International Development. It permits AID to avoid the complexity of dealing directly with the various industries that need help, whereas the non-profit, largely governmental nature of the applied research institutes, make them suitable for direct interaction with U.S.

government agencies. Since the institutes are staffed mostly with people of their own countries, they are readily able to make the necessary contacts with local industries which need their help. Also, since they are funded mostly by their own governments, this provides leverage for any technical help that the U.S. wishes to provide to the country in question. Linkages between the industrial research institute in a developing country with a number of research institutes and universities in the U.S. makes it much easier for the IRI to find the advanced technical knowledge it needs for specific cases, and makes it possible to keep its own staff down to a minimum. An organized effort to provide a less developed country with advanced energy technology will find that a local industrial research institute is a very convenient way of implementing technology transfer.

Industrial research institutes in developing countries have had their difficulties. According to Blackledge (1), "the general consensus seems to be that their success has been marginal at best. Brown (3) says: "As the role of science and technology in the development process is better understood, a point of weakness looms: the limited capacity of developing countries to organize research and to apply it productively."

However, one must remember that the barriers to technological innovation are formidable, even in the United States. They have been well studied and are well documented. The additional difficulties of scarce resources, typical of developing countries, makes a difficult task even more so.

The emerging concept of a technology delivery system is beginning to shed some light on the process of technical innovation, and to provide a theoretical framework for government planning (4). The notion of a technology delivery system (TDS) was employed by the National Academy of Engineering (5) to represent the complex processes by which knowledge in natural and social sciences is deliberately applied to achieve desired outputs of consumer amenities and social values. To illustrate, the complexity of a technology delivery system with which a government has to deal to bring about civilian use of government funded R&D is shown in Figure 1. This is a simplified representation of the TDS for solar heating and cooling of buildings in the U.S.A. To bring about solar heating and cooling of buildings in a developing country, it will be necessary to map out the technology delivery system for that country and the role of the industrial research institute as a component of it. In addition, one has to remember that even in the same country, there can be a different technology delivery system for each different technology.

Fig. 1. Technology Delivery System for Solar Heating and Cooling of Buildings - Present Federal Role.

In the report by Blackledge (1) there are glimpses of the role of the industrial research institute in relation to the technology delivery system, even though the TDS is not referred to explicitly. For example, he says, (p. 9) "Since it is impossible to evaluate an institute without examining its interrelated microcosm, representatives of development banks, government ministries, chambers of industries, etc. were interviewed to the extent possible."

To sum up, industrial research institutes in a developing country can be a very convenient organizational arrangement for transferring advanced energy technology from the U.S.A. and to a country, and for implementing its use in the host country. To do this effectively, the technology delivery system in the developing country must be mapped out, the role of the research institute as a component clearly understood, and the necessary government measures taken to diffuse readiness for the new technology to all the components in the system. This is an essential part of planning a successful technology transfer, and an industrial research institute can play a major role in the planning process itself.

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Appendix H

Examples of
Industrial Research Institutes
in Developing Countries

from

The Industrial Research Institute
in a Developing Community

by

James P. Blackledge
Associate Director
Denver Research Institute
University of Denver
Denver, Colorado 80210

31 August 1975

Contract No. AID/csd-3316

Korea Institute of Science and Technology (KIST)
P.O. Box 131, Dong Dae Mun
Seoul, Korea

Type: Autonomous institute, able to receive funds and other support from the government, but without audit control or fiscal expenditure approval controls.

Board: Board of Trustees of 12 members; three are industrialists. Others include: Vice Ministers of the Economic Planning Board, Science and Technology, Commerce and Industry; representatives of Korea Advanced Institute of Science, Sogang University, Battelle Memorial Institute, USAID/Korea; the KIST auditor, and the KIST Vice President for Administration.

President: Hahn, Sang Joon

Staff: 1973 total of 765; four top management, 300 professional R&D staff, 58 in administration, 185 skilled workers, 202 assistants, 20 others.

Affiliations:

Associated with 22 national associations and organizations. Working agreements with three universities in Korea. Affiliated with Battelle Memorial Institute; New Nippon Steel Corporation, Japan; Sharp Corporation, Japan; Mitsubishi Research Institute, Japan; and Research Triangle Institute, U. S. Affiliated with Ocean Research and Development Institute and Shipbuilding Industry Technical Services.

Finances:

1973: US\$4,880,235 in gross research volume, US\$417,960 in gross overhead, US\$2,540,800 in gross operating expense, US\$2,951,850 in non-research income (interest income from endowment fund deposits), US\$738,630 net income. Of this, 52 percent was derived from contracts and 46 percent from government sources. In 1974, the gross research income was US\$6,200,000 with 57 percent derived from contracted services.

During the first Five-Year Economic Development Plan for Korea (1962-1966), the manufacturing and mining sectors in Korea were growing at an annual rate of 14.8 percent. It became obvious to the government that an organized effort was required leading to long-range development of science and technology to support such industrial growth, starting with the nucleus of a strong, autonomous R&D center in Korea.

As a result of an agreement reached between President Park of Korea and President Johnson of the United States, the U. S. agreed to provide assistance and guidance to Korea in establishing a multidisciplinary, industrial R&D institute in Korea--the Korea Institute of Science and Technology. Battelle Memorial Institute became KIST's "sister institute" and provided advice, counsel, assistance in determining areas of research needs for Korea, etc. Principal facility designs, selection of staff, primary areas of research concentration, and relevance to Korea's priority technological needs were, however, managed by the first President of KIST, Dr. Choi, Hyung Sup, now Minister of Science

and Technology and Dr. Hahn, Sang Joon, now President of KIST. Perhaps the most important aspect of KIST's development was the successful effort to persuade experienced Korean scientists and engineers, trained and working abroad, to return to Korea for employment in KIST.

KIST was incorporated in February 1966 as a not-for-profit corporation existing for the purpose of conducting applied research and providing technical services for industry and government and for the general benefit to the country's economy. KIST was intended to be the focal point for transfer to Korea of world technology and the adaptation of this technology to Korea's needs, rather than a basic research institute whose primary purpose would be to conduct basic research and impart new knowledge. This distinctive applied R&D emphasis remains as the cornerstone of KIST goals and objectives today.

It is difficult to estimate accurately the impact on KIST's effectiveness and productivity, of strong Korean-U. S. Government support, strong Korean leadership, and ample funds to build a well equipped institute and develop a highly capable professional staff. Certainly, it is clear that in a short span of ten years, KIST has achieved an enviable position as an effective technological institute; the extent of KIST contracted services to industry demonstrates this.

During KIST's formative stages, techno-economic surveys were conducted to determine Korean industry priority technological needs. Surveys were made in 25 different industrial sectors involving some 600 industrial plants. On the basis of this survey, KIST established the following as principal areas of concentration: materials science and metallurgical engineering; electronics and electrical engineering; mechanical engineering; chemistry and chemical engineering; food technology. Subsequently, industrial economics, information management and dissemination, computer services, and model machine shops activities have been added.

Specific projects have included work on high temperature materials, solid state physics, physical metallurgy, thermo-hydraulics, control and instrumentation, shipbuilding, ocean engineering, electronics, semi-conductor devices, agriculture products processing, animal foodstuffs, food processing, food resources, polymers, liquid state chemistry, lubricant technology, extractive metallurgy, plastics, construction engineering, technical economics, city and regional planning, packaging development. Several pilot plants are in operation. The products are sold and revenue is used to further develop the pilot plant activity.

During the period 1967-1973, KIST received 831 contracts from clients, totalling approximately US\$4,200,000. During this period, industrial contracts amounted to an average 26 percent of income. In 1973, industry-sponsored projects accounted for 51.9 percent of contract income (out of a total income of US\$4,880,235).

KIST does conduct a small amount of in-house research (two percent) from its own funds, and permits senior staff to undertake research of their own choosing, so long as the research is directed toward an anticipated applied or industrial need. Nearly all staff time however (75 percent to 90 percent) must be devoted to sponsored programs.

During 1973 about 20,000 advanced foreign technologies were analyzed, and some 4,000 of these were included in the KIST "General Survey of Overseas Technology." Over the period 1967-1973, 131 patent applications were made, of which 52 had been approved and registered. KIST estimates that its R&D program have contributed about US\$20 million to the Korean economy.

KOREA INSTITUTE OF SCIENCE AND TECHNOLOGY KIST

Instituto Venezolano de Investigaciones Científicas (IVIC)
Venezuelan Institute of Scientific Research
Apartado 1827
Caracas, Venezuela

Type: Semi-autonomous institute under the Ministry of Health.
Board: Five directors; the IVIC Director and Sub-Director, and one representative each from the National Council of Universities, the Ministry of Education, the Ministry of Health. A Commission for Technology advises the IVIC Director on programs for applied R&D, industry contacts and promotion, national priorities and needs, and IVIC entry into new activities. The Commission consists of the IVIC Director; the two technological center directors and Executive Secretary, the president of the national metallurgical company, the president of the national petroleum company, one representative from private industry, and one representative from an industrial training foundation.
Director: Luis M. Carbonell
Staff: 1975 total of 1,100; 200 professional, 200 administrative, 300 technical supporting, 400 other.
Finances: 1975 operating budget US\$14.3 million, of which US\$1.5 million is from contracted services. Anticipated 1976 budget of US\$21 million, including US\$4 million from contracted services.

IVIC was established in 1959 as a semi-autonomous, government-owned institute with principal emphasis directed toward basic research in the areas of biophysics, biochemistry, microbiology, experimental medicine and nuclear physics. A technological center was established in 1971 so that IVIC could enter into applied research and development. In 1973, the Centers for Chemistry and Petroleum, and Engineering and Computation were established, which are dedicated primarily to applied research, pilot plant operations, commercial testing, and contracted services. Areas of emphasis are: petroleum, chemistry, organic, analytical and organometallic chemistry, metallurgy and materials, electronics and electrical engineering, mechanical engineering and environmental engineering. The original IVIC departments continue to focus principally on basic research, although attempts are being made to link such research more closely into the R&D activities of the IVIC technological center.

The IVIC Center for Advanced Studies is accredited by the Government to offer academic and research programs leading to the M.S. or Ph.D. degree. Classes are taught by IVIC professional staff and students do their research on IVIC projects. Specialized short courses and professional training are also offered to persons from industry, public enterprise, and government agencies.

IVIC is in the process of building a pilot plant park which will be used to carry bench research results into a demonstration phase. Units of the park will also be available to industry on a lease basis to undertake trial runs, investigate product improvement possibilities, train their own staff. etc.

The IVIC Technological Center is undertaking an aggressive program of industrial contacts and promotion of applied R&D. IVIC-industry seminars have been initiated to acquaint industry with IVIC capabilities and interests and so that IVIC can learn about industry needs. Analysis and test activities are recognized as essential to effective IVIC-industry liaison, but the volume of such activities is beginning to create conflicts with organized research activities using the same laboratories and equipment.

IVIC salary schedules are tied to a national professional salary schedule, and are considerably lower than comparable industry schedules, thus creating staff recruitment and retention. A policy, relating back to IVIC's original emphasis on basic research, ties salary increases and promotion to publication of papers in refereed journals, and thus imposes an additional constraint on those IVIC staff who are involved in contract research which may or may not provide publication opportunities.

INSTITUTO VENEZOLANO DE INVESTIGACIONES CIENTÍFICAS
IVIC

Instituto de Investigaciones Tecnológicas (IIT)
Institute for Technological Research
Avenida 30 No. 52-A-77
Apartado Aéreo 7031
Bogotá, D. E., Colombia

Type: Autonomous institute under Ministry of Economic Development.

Board: Board of Directors, five members.

Director: Dr. Norton Young L.

Staff: 1974 total of 122; 38 professional, seven administrative,
36 technical supporting, 41 other and six part-time.

Affiliations:

Cooperation with a number of international organizations and agencies. Linkage with Denver Research Institute. Associated with a development company.

Finances:

1975 operating budget US\$780,000; 30 percent provided by the Agriculture Bank, Bank of Republic, Federation of Coffee Growers, Colombia Petroleum Company and Industrial Development Institute; 70 percent provided by industry, government, and international sponsors.

IIT was established in 1958 through the patronage of the Banco de la Republica, Caja de Cudito Agrario, and Federación Nacional de Cafeteros to undertake applied research directed toward the industrial and economic development of Colombia. The former Armour Research Foundation (now Illinois Institute of Technology Research Institute) provided organizational guidance and assistance. UNIDO provided funds for equipment and provided experts on a counterpart basis. The subsidy received by IIT has increased very little since IIT's founding, so that today such subsidy amounts to 30 percent of IIT's operational budget requirements. The balance is derived from contracts (mostly short-term) from the private sector or government enterprise.

IIT's activities are conducted through four operating divisions: Applied Research, Consultation, Industrial Services, and Administration. Major areas of involvement include: applied research in chemistry, food technology, industrial microbiology, mineral products and raw materials, technical assistance and consultation in food production, metal-mechanical, natural resources, construction, etc. Activities carried out by the Institute include: techno-economic analyses; collection of technological information; quality control, standards, and performance testing; chemical, biological and physical properties testing; industrial troubleshooting; and pilot plant operations. Specific areas of study have included food processing and dehydration, protein enrichment of bread and pasta flours and milk substitutes, concentrated fruit juices, quality control of agricultural chemicals, coal, brick, clays, metal products.

IIT is establishing an aggressive promotional campaign with frequent staff visits to industry, topical seminars for industrial sectors, training of industry staff, etc. The Institute provides technical assistance on a full cost recovery basis, although very small industries are assisted.

to the extent possible, on a no-fee basis. IIT does not have a long-range plan at the present time, although this is in the process of development through its linkage with DRI. IIT staff members are being brought to various centers in the U. S. for specialized training which will establish in IIT capability and experience in problems of quality control and standards, tariffs and trade barriers, technological information and technology transfer, food and drug restraints, etc., all directed toward assisting Colombian industry to increase its exports.

IIT has a good record of assistance to industry and government enterprise. Investments resulting from completed research and technical assistance in recent years have amounted to more than US\$55 million. IIT has conducted 2,200 projects for industry, provided more than 500 consultations, and completed 83,000 product analyses.

IIT is faced with the same general research difficulties that persist throughout Latin America. Industry in Colombia is retarded, private capital is hard to attain, and markets are limited. Large industry goes to foreign institutes for their answers, medium-sized industries do not recognize their research needs, and small industries cannot afford the service. Industry remains ignorant of the concept behind research institutes and feels services should be free. IIT and DRI are jointly conducting a series of seminars for the Colombian Industrial Association for Development (ANDI) in an attempt to partially overcome this problem. Further efforts are directed toward joint research and technical assistance, through the linkage, to specific needs of small industries.

Instituto Centroamericano de Investigacion
y Tecnologia Industrial (ICAITI)
Central American Research Institute for Industry
P. O. Box 1552
Guatemala City, Guatemala, C. A.

Type: Autonomous institute established as regional integration organization by Governments of Central America to provide research services to industry.

Board: The Ministers of Economy of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua.

Director: Gabriel Dengo

Staff: 1974: 79 professionals, 104 administrative, 20 trainees.

Affiliations:

United Nations Development Programme, Organization of American States (OAS), Secretaria del Integración Económica de Centro América (SIECA), Banco Central de Integración Económica (BCIE), linkages with Denver Research Institute (DRI) and CODOT (Universities of California, Michigan State, Rhode Island, Wisconsin, Washington), working agreements with Universities of San Carlos, Guatemala, Costa Rica, Honduras, the Food Technology Institute of the Banco Central de Nicaragua, and a large number of national and regional organizations involved in Central American common market economic and industrial development.

Finances:

1955-1969: U. N. provided the majority of funds through its special assistance program, with US\$52,000 per year subsidy from each Central American country. Since 1969 ICAITI has operated with funds from the governments, industry and outside sources. 1974 operating budget was US\$1,446,000 of which the government subsidies were US\$260,000 or 17.9 percent, the balance was earned from contracts or agreements with industry, governments, and international sources.

ICAITI was established as a regional research organization in 1955 as a result of action taken by the Central American Governments of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua on the recommendations of the Economic Cooperation Committee of the Central American Isthmus of the United Nations Economic Commission for Latin America. ICAITI's objectives, originally and now, are to provide advice, counsel, and technical assistance to Central American Common Market industry, government entities, and public enterprise.

ICAITI, since its inception, has focused major effort on research directed to utilization and exploitation of natural resources, development of standards and test procedures for agricultural production, mining, domestic and export industries, artisan occupations and trades, etc., technical assistance and troubleshooting related to reducing industry production costs, improving production techniques, discovering useful by-products, cooperation with government entities, CACM integration organizations, universities, and other technical organizations

in the promotion of scientific and industrial research, and the training of researchers, technical experts, artisans, and specialized workers.

The current ICAITI divisions are: Applied Research, Industrial-Technical Services, Standards, Applied Geology, Analysis and Tests, Scientific and Technological Development, Documentation and Information.

ICAITI has gained considerable experience in methodologies for identification and assessment of technologies, suitable to use in Central America, as a result of involvement with regional as well as international organizations. In the past decade, ICAITI has conducted 400 research studies, completed 2,800 certificates of quality, 11,000 analyses and tests, and has established 209 standards relating to raw materials, production intermediates, and finished products.

ICAITI has well equipped and staffed laboratories for organic and inorganic chemistry, leather, pulp and paper, textiles, food technology, industrial microbiology, and operates pilot plants as an essential element of the investigations undertaken in the above laboratories. In addition to R&D, testing, etc., ICAITI conducts feasibility studies, economic analysis and marketing studies, and industrial consultation. Applied research programs include industrial use of agricultural products, industrial microbiology, fermentation, geology and mining. ICAITI is a focal point in Central America for management and dissemination of technological information, and provides direction and leadership to a Central American network of organizations who disseminate needed information in their own countries.

Until United Nations financial support came to an end in 1968, ICAITI tended to concentrate more on internal projects of general interest than on specific contracts to solve industrial, national, or regional priority problems. Cessation of U. N. support, coupled with awareness that the governments were not inclined to increase their subsidy, forced ICAITI to undertake aggressive promotion and program activities and to seek financial support from a wide variety of entities, through the mechanism of contracted services. That this effort has been successful is best demonstrated by considering the following: in 1969, the ICAITI budget was approximately US\$480,000, of which 54 percent was derived from government subsidies; in 1974, the government subsidies amounted to less than 18 percent of the ICAITI operating budget of US\$1,446,000.

INSTITUTO CENTROAMERICANO DE INVESTIGACIÓN Y TECNOLOGÍA INDUSTRIAL
ICAITI

Instituto de Pesquisas Tecnológicas (IPT)
Institute for Technological Research
Caixa Postal 7141
São Paulo, Brazil

Type: State Government institute responsible to the Governor through the President of the Council of Administration.
Board: Council of Administration consists of two representatives from the College of Engineering, University of São Paulo; two representatives of the State Council of Technology (CET); one representative of the Federation of Industries; one representative from the Engineering Institute; the Superintendent of IPT; and one observer from the State Secretariat of Finance.
Superintendent: Dr. Alberto Pereira de Castro
Staff: 1974: total of 1,388; 393 professionals, 440 technical supporting, 228 administrative, 327 others.

Affiliations:

University of São Paulo, Development Bank of São Paulo; National Bank for Development (BNDE); Science and Technology Program (CET) of State of São Paulo; sectoral system of Science and Technology, Ministry of Industry and Commerce; Brazilian National Research Council; Brazilian Association of Standards and Tests; involvement in a variety of commissions, councils, societies in Brazil; linkages through CET with the U. S. National Bureau of Standards (NBS), and the Denver Research Institute (DRI); working agreements with nearly all research centers in Brazil such as CETEC, CEPED, CIENTEC, INT, ITAL, ITEP.

Finances:

1974 operating budget US\$14.7 million; US\$7.8 million for personnel, US\$5.6 million for facilities development, US\$1.3 million for other expenditures. Thirty-six percent of the operating budget is earned income from contracts. IPT is unable to accumulate or carry over surplus funds, but has discretionary control over expenditure of earned income, including payment of bonus and incentive payments to researchers working on contracts. Funding support for external technical assistance (NBS and DRI) received from Science and Technology Program of State of São Paulo via a technical assistance loan from the U. S. Agency for International Development.

IPT originated as a State testing laboratory in 1936, and was reorganized into a multi-purpose technological institute in 1944. The Institute's salary schedules, management of expenditures, and other operational policies are still influenced by State civil service regulations. IPT is currently attempting to achieve the status of a state-owned autonomous corporation, hopefully during 1975. This corporate status, while still permitting IPT to receive state and federal funds, will provide the IPT management greater flexibility in recruiting, training, and retaining staff, in greater discretionary control and utilization of income and other funds, and in more effective

working relationships with clients.

IPT's functions include applied research, standards and performance testing, chemical, biological, and physical testing, technical information services, pilot plant operations, and training of both professional and non-professional people, for IPT as well as for industry. Technical divisions are: Civil Engineering, Chemistry and Chemical Engineering, Forestry and Wood Products, Mechanical Engineering, Metallurgy, Mineral Treatment, Mining and Applied Geology, Naval Engineering, and Technical Information. New buildings completed or nearing completion during 1974 included: Center for Instrumental Chemical Analysis, Technological Information Center (3,000 m²), Mining and Applied Geology Building (2,200 m²), a ceramic laboratory, Physical Metallurgy Laboratories (6,000 m²), Paper and Cellulose Laboratories (4,000 m²), Geotechnical Laboratory (2,600 m²), the Naval Engineering Experimental Tank.

IPT has consistently increased its contracts and service agreements with industry and public enterprise. In 1970, some 17,000 certificates of testing were issued; in 1971, the number was 25,300; in 1972, the number was over 30,000 certificates. The number of contracts has increased from 38 in 1971 to 188 in 1974. Of the 188 contracts operative in 1974, 39 provided technical support to government-owned companies and/or agencies, 69 provided technical assistance to Brazilian industry and multinational corporations, 25 contracts resulted from industry requests for specific research, and ten agreements provided consulting services in engineering.

IPT as yet has no capability in industrial economic analysis and market feasibility studies, although staff are being trained to undertake such activities. Liaison with industry and government is excellent, and is expected to improve. A current major problem relates to difficulty in retaining competent staff. Salary schedules are considerably lower than industrial levels and IPT staff turnover rate is around 15 percent. Due to Brazil's current rapid rate of growth, availability of technological personnel is extremely limited.

Appendix I

An Industrial Energy
Conservation Program Matrix

Applied
Technology
and
Demonstration

I-I-I-III

Industry Function	Chemical	Petroleum Processing	Primary Metals	Pulp & Paper	Cement	Agric. & Food	General
Waste Energy Utilization							
Process Changes							
Materials Optimization							
Incentives							
Guarantees							

Matrix For Planning and Implementing Industrial

Conservation Programs

In each industry category an analysis is made of the five functions shown. From this analysis specific projects are derived for better utilization of waste energy, for more energy efficient processes, and for the optimum use of materials. Evaluation is then made of incentives and guarantees which might be necessary to encourage the specific industrial energy conservation programs.

Appendix J

Conferees

People Conferred With

OAS Marcelo Alonzo, Director, Department of Scientific Affairs
 Carlos Martinez-Vidal, Office of Scientific Affairs

AID Dr. John Daly, Deputy Director, Office of Science and
 Technology, AID
 Roger Moeller, Office of Science and Technology, AID
 (Technology Transfer)
 Donald Finberg, Director, Operations Appraisal Staff, AID
 W. M. Feldman, LAC/DR, AID
 Richard Weber, Director, South American Affairs, AID
 Barry Riley, Peru Desk Officer, AID
 Allan Poole, AID
 Samuel Boskin (energy), AID

James P. Blackledge, Associate Director, Denver Research Institute

David Donaldson, Eng'r., Environmental Section, Pan American
Health Organization

Key Erecon Personnel:

Dr. Arthur A. Ezra
Dr. Raymond L. Bisplinghoff
Gerardo R. A. Cahn-Hidalgo

Dr. Nam P. Suh, Director, Laboratory for Manufacturing and Productivity
Professor of Mechanical Engineering, M.I.T.

DOE Personnel

W. Porter, U.S.-Peru Cooperative Energy Program
R. Gerson, International Energy Development Program

World Bank

Alfonso Zavala, Water and Sewer Matters, Latin America
Philip Owusu, Energy Economics, Latin America
Louis Landau, Economist for Latin America

Argonne National Laboratory

T. R. Janson, Office of Program Management Support

C. W. Ledsy, Liaison with Department of State

Brookhaven National Laboratory

P. Palmedo, Policy Analysis Division

U.S. Embassy, Lima

Harry Stein, Economics and Energy Officer

Interamerican Development Bank

Gustavo Calderon, Specialist, Engineering Section

Appendix K

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