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

Volume 3 of 4 Vols.
Annexes 2-7

August 1979

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

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ANNEX - 2

REPORT ON THE INDUSTRIAL DEMAND SECTOR OF PERU

BY

BARRY G. TUNNAH

GORDIAN ASSOCIATES

U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

SEPTEMBER, 1978

The data presented in this report have been derived from published documents and a limited series of interviews with Peruvian government agencies and state-owned operating companies. A partial review of data, with emphasis on the oil refining sector, has been made in the course of the "Brookhaven" sessions to develop energy options, but no extensive review of other sectors has been performed. Subject to this limitation, the information presented on existing processing facilities and planned expansions is believed to be a reasonable reflection of activity in specified areas of the mining, agricultural and industrial sectors of Peru.

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A. SUMMARY

This report presents the results of a brief study of industrial, mining and agricultural sector energy demands in Peru. The objectives of the study were to establish current energy demands and sectorial activities, and to project future energy needs through the year 2000. This information is intended for use by Brookhaven National Laboratory in their "Reference Energy System" model which is being used as a primary tool for an assessment of the energy supply-demand situation in Peru.

With respect to energy demands, this study covers the following subsectors:

- Mining and non-ferrous metals
- Iron and steel
- Cement
- Oil refining
- Petrochemicals
- Chemicals
- Fertilizers
- Agriculture (major crops)

Total energy demands for these subsectors were developed for 1976, 1985 and 2000, assuming full capacity operation for the majority of the plants. The estimated demands are as follows:

	10^{15} Joules per Year		
	1976	1985	2000
Mining and non-ferrous metals	28.9	51.6	92.9
Iron and steel	8.6	22.2	80.5
Cement	10.0	17.0	32.4
Oil refining	6.6	11.3	17.9
Petrochemicals	0.3	0.4	7.5
Chemicals	2.5	5.5	7.5
Fertilizers	6.6	14.0	37.3
Agriculture	6.2	8.0	12.3
	69.7	130.0	288.3

A number of potential options for reducing energy use in these sectors were developed. These include the following:

(1) Increased coal use

(2) Improved energy efficiency in the manufacturing sector

(3) Use of agricultural wastes as fuel

(4) Possible displacement of oil by hydroelectricity

(5) Use of geothermal energy

(6) Increased use of waste materials for the cement and construction industries

(7) Possible promotion of cogeneration systems (electricity/steam)

The full list is given in Section N of this report. Finally, some suggestions are offered for the improved usefulness and analysis of energy-related data. There appears to be a reasonable amount of information on electricity supply and demand readily available in Peru, but there is a serious deficiency in data on fuel usage, which betrays a lack of appreciation of the "systems" approach to energy analysis and planning. At a practical level, this lack of appreciation is demonstrated by the "gas turbine syndrome", where a deficit in electrical supply to a project is almost always made up by the installation of yet another gas turbine. The implications for energy resource consumption of this approach are rarely, if ever, analyzed. It is therefore strongly recommended that attention be paid in any follow-up activity to the training of appropriate government and operating agency personnel to the importance of a rational systems approach to energy resource planning, and thus to the development planning of the nation.

B. INTRODUCTION TO THE STUDY AND THE PERUVIAN INDUSTRIAL SECTOR

The study which forms the basis for this report was conducted over a two-week period in June 1978 with a further week of review activities and plant visits in August. The primary objectives of the study were to develop energy demand data for use in an assessment of the energy supply-demand situation for Peru, being conducted by Brookhaven National Laboratory on behalf of the Department of Energy (US-Peru Cooperative Energy Assessment Program).

With such a short time available for this phase of the study, it was necessary to be highly selective of the industrial, mining and agricultural subsectors chosen for detailed review. The following areas were ultimately covered, to a greater or lesser extent, through tne examination of published documents and by a series of interviews within Peruvian government ministries, state-owned operating companies, and the private sector (see Section P for a list of contacts):

- Mining
- Non-ferrous metals production
- Iron and steel
- Cement
- Oil refining
- Petrochemicals
- Chemicals
- Fertilizers
- Agriculture (major crops)

The Peruvian industrial, mining and agricultural sectors are diverse and well-developed. For example, in addition to the subsectors chosen for study, there are significant activities in the following areas:

- Shipbuilding
- Boilermaking
- Heavy engineering
- Electrical machinery
- Automotive industry
- Machine tools
- Synthetic fibers
- Pharmaceuticals
- Wood products
- Brewing
- Fishing
- Food processing
- Electronics
- Glass products
- Synthetic resins
- Plastics (consumer products)
- Rubber products
- Textiles
- Pulp and paper

In fact, the subsectors covered in this study represented about 50% of the industrial sector energy demand in 1976 (rising to about 70% by 2000) and close to 100% of the mining sector for the period under study.

To put the industrial, mining and agricultural sectors in perspective, the GDP arising from basic activities in 1975 was as follows:

	(Millions of 1970 US $)	%
Agriculture	993	24
Fishing	64	2
Manufacturing	1733	41
Mining and Petroleum	304	7
Construction	388	9
Government	692	17
	4174	100

Source "Peru in Figures, 1976" Banco Continental, Lima.

Finally, indicators of sectoral activity are given below for some major areas, including those which formed part of this study:

(1973=100)	1975	1976	1977
Overall manufacturing sector	117.6	123.2	115.2
Fishmeal	167.3	206.6	114.8
Food, drinks, tobacco	117.3	121.1	117.0
Textiles, cloth, leather	104.2	111.1	94.6
Paper and printing	98.3	103.3	94.4
Petroleum derivates etc.	123.4	133.2	126.9
- industrial chemicals	130.8	143.2	156.1
- misc. chemicals	126.3	139.6	125.0
- petroleum refineries	114.9	115.0	115.9
- rubber products	118.9	140.1	116.8
- misc. plastic products	123.3	121.0	109.1
Non-metallic minerals	124.1	129.5	120.9
Basic metals	104.2	105.2	147.1
- iron and steel	124.7	104.4	123.3
- non-ferrous	92.8	105.6	160.5

Source "Indicadores del Sector Manufacturero, Enero-Diciembre 1977", Ministerio de Industria, Comercio, Turismo y Integracion, Lima.

With a few notable exceptions, the indicators show that the manufacturing sector is in decline. This fact, coupled with a large external debt and a deteriorating balance of payments situation, lends urgency to the study of Peru's energy supply-demand situation in the overall context of national development.

C. COMMENTARY ON INFORMATION AVAILABILITY

Although the study on industrial and agricultural sector energy demands was carried out over a very brief period of time, certain aspects of information availability and usefulness became apparent quite quickly. The following comments are therefore offered in the hope that they may provide background to the availability of data for further analyses, the potential for changes in data gathering procedures, and on the general accuracy of the numbers presented in this report.

C-1 Adequacy of Current Information on Energy Supply and Demand

A great many reports of a statistical nature are published each year by the Peruvian government. Some of these cover industrial and agricultural production in terms of physical units, others report this production in terms of soles. There are regular reports of indicators of industrial production. With respect to energy use, there are reports on electricity consumption and generation for the country as a whole, by regions and, to some extent, by sector of the economy. There appears to be little attempt to break sectoral consumption down into subsectors corresponding to discrete industrial activities, i.e., steel, cement, fertilizers, etc. With respect to fossil fuel use (coal, coke and petroleum-based energy resources), statistics are almost non-existent in publically-published form. Essentially all this kind of data that was made available in the course of this study was obtained, directly or indirectly, from Petroperu (with valuable contributions from Siderperu and Centromin on their specific activities).

With regard to new projects in the industrial and agricultural sectors, it proved relatively easy to gather data on anticipated electrical loads, but even these were not always translated into annual energy requirements (as kWh, for example). Again, data on fuel use was almost entirely unobtainable, either from published sectorial plans or from individual operating companies.

In terms of its usefulness for energy policy analysis, the data available in published (and centralized) reports is clearly inadequate. The emphasis on electricity indicates a lack of understanding of the "systems" nature of energy use and energy planning.

Indeed, the potential problems of failing to fully appreciate the national energy balance as a total system are well illustrated by the prevalent "gas turbine syndrome". Where electricity needs are greater than existing installed capacity, there is often inadequate lead time to arrange for the delivery of hydroelectric power. The simple answer is to install yet another gas turbine, which will provide electricity at a low, once-only, capital cost and at a continuing high operating cost. There is apparently little thought given to the quantity of fuel required by the gas turbine, nor is there an appreciation of the cost to the country in terms of reduced petroleum availability for the generation of badly-needed hard currency. The gas turbine syndrome is particularly unfortunate in a country that has under 2000 MW installed hydroelectric capacity, yet has an economic hydroelectric potential for perhaps 50,000 MW.

C-2 Acquisition of Necessary Energy Information

For the purposes of evaluating energy options and for developing soundly based, energy-conscious, national development plans, it is clear that much data on fuel use should be collected. In the short term, this effort will require further discussions with major fuel consuming subsectors of the industrial and agricultural economies, and a detailed examination of their records. This data should be reconciled with marketing data from Petroperu. However, it is not suggested that all consumption elements be investigated and identified in the evaluation of options. This would be a major task, requiring many manhours and a significant calendar time, perhaps two months. Instead, each option should be examined as to data deficiencies and a highly specific data acquisition program should be developed and performed. The full cooperation of consuming entities and Petroperu will be required but, in view of the excellent assistance provided to date, this is not viewed as a potential problem.

C-3 A National Energy Information System

While data on electricity use requires some disaggregation to enhance its usefulness for planning and analysis purposes, the conspicuous lack of data on historical, current and future energy flows corresponding to fossil fuel resources demands urgent attention from the Peruvian government. Of course, it should be recognized that the lack of such data is by no means unique to Peru: indeed, the appreciation of the "systems" nature of energy resources and materials resources is lacking in many countries, often at the government policy-making level. Proper planning of development should take energy resources fully into account, and this includes an awareness of the indirect energy investment in materials (materials of construction, for example, may be amenable to inter-substitution with beneficial energy effects, or recycling of scrap material may provide a significant contribution to improved energy efficiency).

The reorganization of current statistics-gathering efforts (and the organization of data collection for new projects) to provide the required data on the consumption of all energy resources will be a major effort. An important first step will be the education of those most directly involved in the gathering and analysis of statistics in the systems analysis approach to energy planning. The "attitude" of these people will be crucial to the timely development of a national energy information system, because they are familiar with current procedures and will therefore be most appreciative of current shortcomings once the concept of a systems approach has been learned.

A second step would be the requirement for all new projects in the public and private sectors needing electricity connections to submit a full account of all materials and energy flows for the project, whether or not these are directly related to electrical consumption. This data will provide valuable input to the planning function of the Ministerio de Energia y Minas. Further specific steps should be developed in cooperation with the appropriate Peruvian government agencies and their personnel.

Finally, it should be mentioned that a proper analysis of energy options cannot be undertaken without due concern for the marginal (or opportunity) cost of energy resources. In this connection therefore, it is recommended that any training course in energy systems analysis include a thorough grounding in cost analysis.

D. MINING AND NON-FERROUS METALS PRODUCTION

D-1 Introduction

The minerals sector is a particularly important part of the Peruvian economy, typically providing over half the total value of the nation's exports (55.8% of total exports of $1246 million in 1976). A large number of minerals are found in Peru, but those of major commercial (and energy) importance are the ores of copper, lead, zinc, and iron. This section is concerned primarily with copper, lead and zinc extraction.

In terms of quantities produced, Peru ranks seventh in the world with respect to copper (4.5% of world production), fifth for lead (5.4%) and fifth for zinc (6.7%). Peru also produces significant quantities of silver (third largest production in the world, 13.3%). Proven reserves of copper, lead and zinc ores are estimated to be equivalent to about 80, 20 and 25 years at current production levels.

The non-ferrous metals sector is expected to grow (within the constraints of world market prices for exported commodities and capital availability for plant investment) as the government continues to stress the promotion of industries which increase the local added value of the national natural resources. For example, a large new copper refinery at Ilo was brought on-stream in November 1975, Cerro Verde I was commissioned in 1976, as were the Southern Peru Copper Corp. facilities at Cuajone (the largest mine in Peru). Plans for expansions at Ilo, Cerro Verde and a number of other locations have been announced. A new zinc refinery is currently under construction at Cajamarquilla, near Lima, and this is expected to be on-stream by the end of 1981.

With respect to downstream processing, there are many small plants producing a wide range of semi-finished products such as copper rods and wires, lead-antimony alloys, seamless lead piping, zinc-aluminum alloys electric cables, extruded copper sections, metallic powders, sheet copper, screws, nuts and bolts.

D-2 Existing and Planned Production Facilities

The largest consumers of energy (and producers of non-ferrous products) are the government-owned entities Minero Peru and Centromin, and the privately-owned Southern Peru Copper Corporation. Brief descriptions of the existing and planned facilities follow, and further details of the most important plants are given in Exhibit D-1. Locations are indicated in Exhibit D-2, and interrelationships amongst plants in Exhibit D-3.

Minero Peru operates a copper refinery at Ilo in the south of Peru. The refinery was designed for 300,000 MT per year of copper cathodes, produced by electrolytic processes. The first stage, for 150,000 MT/yr. was commissioned in November 1975. Production in 1977 reached 123,456 MT of cathodes (99.99% copper): by-products included muds containing silver, gold, selenium, tellurium and bismuth. The second stage of the Ilo plant is expected to be commissioned by the early 1980's, say 1983.

A major Minero Peru enterprise is Cerro Verde I located near Arequipa. The complex consists of open-cast mines and associated electrowinning plants to produce 33,000 MT/yr of copper cathodes. The complex went into operation in 1976. Feasibility studies for Cerro Verde II, a similar complex to produce 62,000 MT/yr of copper cathodes, are in progress and it is anticipated that this project could be in operation by the end of 1982.

Minero Peru is currently constructing a zinc refinery at Cajamarquilla, near Lima. This is designed to produce 101,000 MT/yr of refined zinc from about 200,000 MT/yr of concentrates. In addition, 190,000 Mt/yr of sulfuric acid are to be produced, as well as smaller quantities of by-product metals (e.g. 335 MT/yr cadmium, 15,000 MT/yr of lead and silver residues). The sulfuric acid will be used for treating the Cerro Verde ores and in the manufacture of fertilizers at Bayovar. Construction of the refinery started in September 1977, and is expected to take 36 months. The plant should be commissioned in 1981.

Other Minero Peru projects in the non-ferrous area include the following:

Tintaya:	Exploitation of 8000 MT/day of copper ores, to produce concentrates.
Michiquillay:	Also to produce concentrates from 40,000 MT/day of copper ores.
Quellaveco:	Also to produce concentrates from 20,000 MT/day of copper ores.
Antamina:	To produce concentrates of copper and zinc from 20,000 MT/day of mixed ores.

Further details of capacities and energy consumption for these new projects appear in the exhibits to this section. Other Minero Peru projects are believed to be quite tentative and therefore are not likely to have a major impact on the energy situation prior to 2000, although there is the prospect of the development of gold mining at San Antonio de Poto: no details were available, however. Minero Peru projects at Bayovar (fertilizers) are discussed in the fertilizer section of this report, and the development of the Alto Chicama coal deposits in the resource section of the study.

Centromin operates the Cerro de Pasco mines and five other mining complexes in the Sierra Central, as well as the metallurgical complex at La Oroya. The capacity of the mines is about 16,000 MT/day of ores (copper, lead, zinc, silver, tungsten), and La Oroya has the capacity to produce 240,000 MT/year of refined metals and 60,000 MT/year of sulfuric acid. Plans include expansion of the mines and concentration plants at Cobriza, Casapalca and Cerro de Pasco, expansion of the copper refinery at La Oroya, and a new lead agglomeration plant at La Oroya.

Southern Peru Copper Corporation operates major facilities at Toquepala and Cuajone, the latter being started in 1976. In 1977, copper production at Toquepala was 97,834 MT and at Caujone 162,359 MT, for a total copper production of over 260,000 MT, equivalent to 74% of total Peruvian copper output.

D-3 Activity Data

Data on the production of a wide range of minerals and metals are found in such publications as the "Anuario de la Mineria del Peru" published by the Ministerio de Energia y Minas, and "La Mineria en el Peru", published annually by Editores Tecnicos Asociados S.A. of Lima. In summary, the major activity data is as follows (based on published data and on figures provided in discussions with the Ministerio de Energia y Minas):

(Thousand MT fine metal)	1973	1974	1975	1976	1977	1978(est)
Copper						
blister	134.0	137.5	85.1	46.8	140.6	-
refined	39.0	39.0	71.5	131.6	177.7	-
concentrates/ores	29.7	35.1	9.2	32.8	14.5	-
total	202.7	211.6	165.8	211.2	332.8	365.0
Lead						
refined	82.9	80.2	71.0	74.1	79.3	-
concentrates/ores	100.5	85.6	83.2	94.9	96.9	-
total	183.4	165.8	154.2	169.0	176.2	182.3
Zinc						
refined	69.0	70.8	65.1	64.7	66.8	-
concentrates/ores	321.6	307.2	299.8	338.6	369.8	-
total	390.6	378.0	364.9	403.3	436.6	469.4
Total Copper/ Lead/Zinc	776.7	755.4	684.9	783.5	945.6	1016.7

D-4 Current Energy Consumption

Accurate statistics on current energy consumption are not readily available, except in the case of electricity where comprehensive data may be obtained for the mining sector as a whole. A breakdown of electricity use by plants is not given. Details of the consumption of other fuels are not normally published. However, a recent report by the Instituto Cientifico y Tenologico Minero (Incitemi) on the possibilities for coal use in Peru ("Economia del Carbon y Coque", November 1977) provides estimates of the disposition of petroleum fuels throughout the industrial sector. The Incitemi data was based on discussions with the supplier of these fuels (Petroperu) and with the major consumers. Data on petroleum fuels use at La Oroya was given by Centromin.

With respect to electricity, it is common practice in Peru for industrial plants to generate much of their own electricity. In many cases, this is done using diesel engines or gas turbines running on petroleum-based fuels. In addition, significant amounts of electricity are supplied from hydroelectric plants. The efficiency of electricity generation by industrial facilities using petroleum fuels is typically around 12.5 kWh per gallon of petroleum (say 11200 Btu/kWh, 30.5% efficiency). Some are significantly less efficient, however, dropping to 5.7 kWh per gallon in the case of one cement plant (Cemento Sur SA, 1975 data).

In summary, the energy used in 1976 in the mining sector, including non-ferrous metal production and iron ore mining (but not steel production) is estimated to amount to about 29 x 10^{15} joules. Details are given in Exhibit D-4.

D-5 Energy Efficiency of Existing Plants

Since the non-ferrous sector produces such a wide and variable range of products, the term "specific energy consumption" has no precise meaning. However, energy consumption may be related, in a very approximate manner, to an activity level based on a total production of copper, lead and zinc:

$$\frac{28.87 \times 10^{15}}{783.5 \times 10} \quad \frac{\text{joules}}{\text{MT}} = 36.85 \times 10^{9} \text{ joules/MT}$$

= 10235 kWh per MT of combined Pb/Zn/Cu.

D-6 Energy Efficiency for New Projects

While the energy efficiency of existing plants is, generally speaking, difficult to establish due to a lack of disaggregated data as well as an inability to define "output" in meaningful terms, data does exist for many of the projected plants in the non-ferrous metals sector.

Data provided by Minero Peru on new projects was used to develop the following energy efficiencies. The primary energy resource in most cases is electricity, and the use of fossil fuels is generally expected to be minimal in these particular facilities (with the exception of the oil fired remelt furnace at Ilo).

Project	Operation	Energy Use, kWh Electricity
Cerro Verde I	Oxide ore (0.95% Cu) to copper cathodes by electrowinning	3525 per MT Cu
Cerro Verde II	Sulfide ore (0.65 % Cu) to copper cathodes by electrowinning route	4711 per MT Cu
Ilo I, II	Concentrates to cathodes (electrowinning)	400 per MT Cu (plus 1000 kWh equivalent for fossil fuels*)
Tintayo	2.0% Cu ores to concentrate	1000 per MT conc.
Michiquillay	0.72% Cu ores to cncentrate	675 per MT conc.
Quellaveco	0.85% Cu ores to concentrate	880 per MT conc.
Antamina	Ores to Cu/Zn concentrates	630 per MT conc.
Cajamarquilla	Ores to refined zinc (electrowinning)	4455 per MT zinc

* Gordian estimate.

Data from Centromin on new projects was expressed in terms of megawatt capacity increases needed to provide power. These were converted to annual kWh consumptions on the basis of 8000 hours operation per year at full load. Current fossil fuel consumption by the Centromin La Oroya smelter results in a consumption figure of about 7800 kWh equivalent per MT copper produced.

In the absence of specific data, rough estimates of energy consumption may be made on the basis of the following figures:

Copper

Ores to concentrates	1000 kWh/MT concentrate (say 3300 kWh/MT Cu)
Concentrate to electrowon copper	400 kWh/MT Cu
Ore to refined copper	3700 kWh/MT Cu

Zinc

Ore to refined zinc	4500 kWh/MT zinc

For comparison, the following figures were taken or derived from "Energy Expenditures Associated with the Production and Recycle of Metals" (Oak Ridge National Laboratory, November 1972):

	per MT Cu
Ore (1% Cu) to concentrate	1800 kWh electricity
Smelting concentrate to blister	6500 kWh equiv. fossil fuel
Refining blister to copper cathodes	200 kWh electricity plus 1000 kWh equiv. fossil fuel

Clearly there can be a wide variation in specific energy consumption according to such factors as the quality of raw materials and their hardness, and the details of the processing technology employed.

D-7 Projected Energy Consumptions

Data on projected plants in this sector were provided by Minero Peru and Centromin and this allows estimates to be made of energy consumption through 2000. Information on plant capacities, maximum electrical loads, electricity and fuel consumptions, and estimated commissioning dates is summarized in Exhibit D-5. Assuming all plants ultimately operate at rated capacity, the total sectoral energy consumption will rise to over 68×10^{15} joules per year by 1985, an increase of 39×10^{15} joules over the 1976 base year consumption. This increase is based entirely on the commissioning of the named projects, and does not make any allowance for any projects which may be developed later, or for changes in the energy consumption of existing plants (due to deterioration of equipment or to renovating and rebuilding old equipment, for example).

There exist many projects in a very preliminary state of investigation which could be fully developed by 2000. In fact, the mineral resources of Peru are such that significant increases in production of many minerals, notably lead and zinc, could take place under favorable economic conditions.

On the basis of an annual increase in sectoral activities between 1985 and 2000 of about 6.5%, the estimated energy consumption of the mining sector will rise to 124×10^{15} joules by 2000.

EXHIBIT D-1

ADDITIONAL TECHNICAL DATA ON NON-FERROUS PROCESSING FACILITIES

Ilo Refinery (Minero Peru)

The fully-completed refinery will have a capacity of 300,000 MT/yr, sufficient for the total output of the two SPCC mines, Toquepala and Cuajone. The refinery consists of two processing sections, the anode plant where blister is melted and remoulded to make copper anodes, and the electrolytic plant which produces copper cathodes.

At the anode plant, the blister bars (over 98% copper) are loaded into two oil-fired furnaces, 330-ton capacity each. The copper is oxidized to burn off sulfur, and then reduced by introducing trunks of eucalyptus. The molten copper is then cast into anodes of about 375 kg. each.

The electrolytic plant consists of 384 conventional cells, constructed of concrete and lined with PVC. The cells take 45 anodes and 46 cathodes. The electrolyte contains sulfuric acid and copper sulfate: current for electrolysis is 20,100 amperes (223 amp/M^2) with a voltage drop of 0.28 volts per cell. The initial sulfuric acid charge was 1500 tons, and about 20 tons per month is required as make-up. The final product is 99.99% pure copper.

Sea water is distilled in a 1500 MT per day desalination plant on site. Steam for electrolyte heating, purification and vacuum ejectors is provided by oil-fired boilers and a waste heat boiler in the anode plant.

Cerro Verde (Minero Peru)

Phase I is designed for the exploitation of an estimated 97 million tons of ores (average 0.65% copper, mostly oxides) and Phase II for an estimated 1000 million tons of low grade sulfides (averate 0.7% copper).

The Phase I processing of the oxides is performed by a hydrometallurgical route rather than conventional pyrometallurgy (smelting and refining). There are four principal stages in the hydro process: crushing, lixiviation (leaching), purification by ion exchange and electrodeposition (electrowinning). After mining, the first stage in processing is primary and secondary crushing. The ore is then deposited in "pads" for leaching with 13-14% sulfuric acid (100,000 tons at a time for about 45 days). The resulting copper sulfate solution is sent to the purification plant (ionic interchange) which consists of two sections: extraction and re-extraction. In the extraction part, an organic solvent separates the copper from acid impurities. The organic copper solution passes to re-extraction where sulfuric acid from the electrowinning section is mixed in. Pure copper sulfate is produced and the organic solvent is regenerated and returned to extraction.

The copper sulfate is pumped off to the adjoining electrowinning plant. Here there are 216 cells (46 cathodes, 47 anodes each). A current density of 17 amps per square foot (12,000 amps) is used in the making of cathodes.

Sulfuric acid inventory is about 20,000 tons, and a consumption of 60,000 tons per year is expected. Power for the complex is generated in two GE turbines, each with a capacity of 16.5 MW.

La Oroya (Centromin)

The smelters and refineries at La Oroya are considered, the most complex metallurgical operation in the world. Facilities include a lead smelter, copper smelter, zinc refinery, electrolytic refinery for copper and lead, the extraction of gold, silver and bismuth, and the production of a variety of companion metals, metal products and chemical products.

Antamina (Minero Peru)

Proven reserves amount to over 120 million MT, averaging 1.56% copper and 1.27% zinc. Silver content is 0.51% and there is also a significant quantity of molybdenum (0.4%). The mine will be developed as an open pit. A 20,000 MT per day concentrator will be constructed at the mine, using conventional crushing, grinding and flotation technology. The copper and zinc concentrates will be pumped along a 200 Km pipeline to the coast for export. There is the possibility that 3000 MT of molybdenum concentrates will be available.

Michiquillay (Minero Peru)

Feasibility studies have postulated a 40,000 MT per year production of 26.3% copper concentrates which will be shipped as a slurry from the mine to the port of Pacasmayo (211 km). The energy demand of 40 MW at the mine is to be met from the Electroperu system, with the energy demand at Pacasmayo met from three 600 KW diesel units.

EXHIBIT D-2

NON-FERROUS METALS: MAJOR MINING AND REFINING SITES

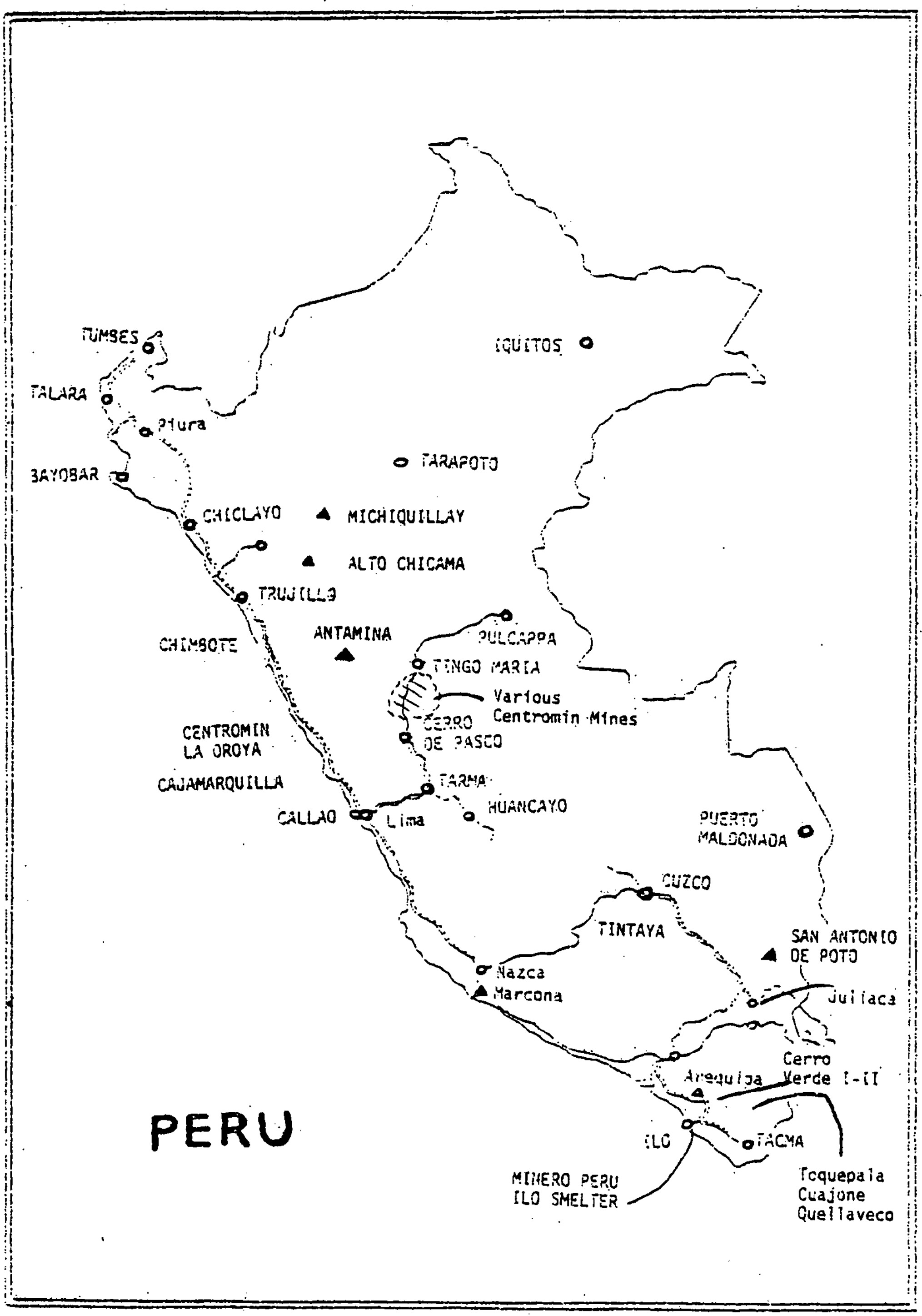

EXHIBIT D-3

SIMPLIFIED DIAGRAM OF THE MAIN ELEMENTS OF THE COPPER INDUSTRY

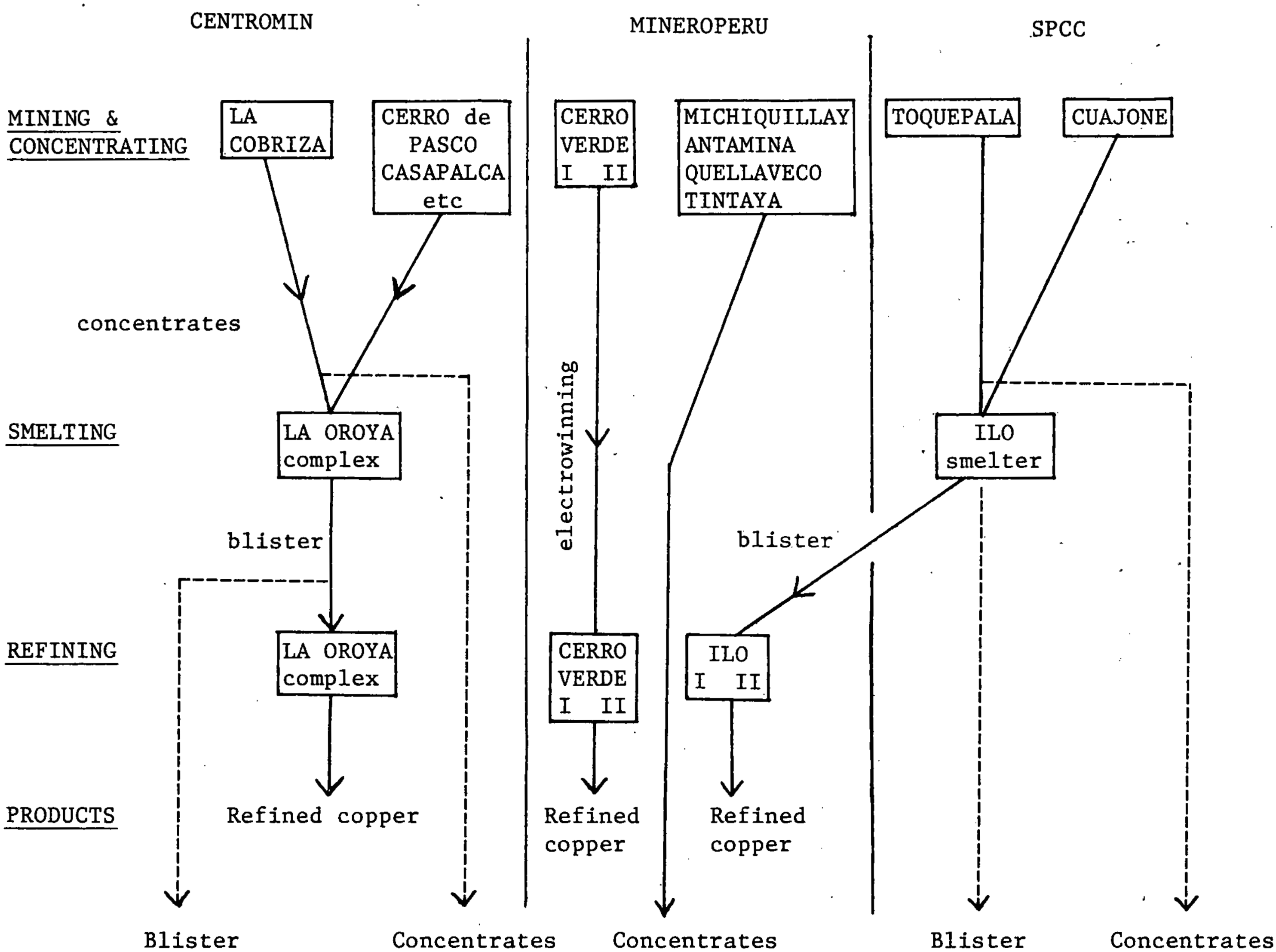

EXHIBIT D-4

ENERGY CONSUMPTION IN THE MINING AND NON-FERROUS METALS SECTOR, 1976

	Basic Units	10^{15} joules
Electricity - 10^6 kWh		
Self generated	1782.0	6.42
Purchased	175.8	0.63
Total	1957.8	7.05
Petroleum fuels - 10^3 bbls		
For transportation uses	1150	7.11
* Process uses	2124	13.13
Total	3274	20.24
for electricity generation, included in the total self-generated figure	1100	6.80
Total to sector	4374	27.04
Coke and Coal - MT		
Coke for La Oroya	40,000	1.21
Coal for misc. uses	12,000	0.37
	52,000	1.58
TOTAL		28.62

* Includes Hierro Peru (pelletizing plant) 390,000 bbl, Centromin (La Oroya complex) 446,000 bbl, Southern Peru Copper Corp. (smelter) 933,000 bbl.

Major Sources

1. "Anuario Estadistica Electrica 1975", Min. Energia y Minas
2. do. 1976.
3. "Economia del Carbon y Coque", Incitemi 1977.
4. II Censos Nacionales 1973.
5. Interviews with Centromin, June 1978.

EXHIBIT D-5
PROJECT INFORMATION AND ENERGY CONSUMPTION ESTIMATES
1976-2000

Key: MP-Minero Peru; CM-Centromin; SP-Southern Peru Copper Co.; P-Petroleum fuels; C-Coke & coal; E-Estimated

Date/Operator	Project	Remarks	Capacities 10^3 MT/Yr. Concentrates	Capacities 10^3 MT/Yr. Ref.Cu.	Energy Efficiencies Fuel 10^3Kcal/MT	Energy Efficiencies Elect. kWh/MT	Electr. Max. load MW	Annual energy consumption with new plants at full capacity: Self-gen.electr.** %	Elec. 10^6kWh	Fossil 10^9Kcal	10^{15}joules
Existing in 1976											
MP	Ilo I	Blister to electro.copper	--	150.0	860	400	7.5	100	60	129	0.756
CM	La Oroya	Conc. to smelted/ ref. copper		60.0							
SP	Toquepala	Ore to blister		130.0				100			
	Others			20.0							
1976*	Totals	See Exhibit D-4	1500.0^E	360.0^E				9	1958	P4836 C 378	28.870
1977	El Aguila	Ore to concentrate	60.0	--	--	1000	9.0	0	60	--	0.216
SP	Cuajone	Ore to blister	--	170.0	6700	300	--	100	51	1139	4.951
MP	Cerro Verde I	Ore to elec-won copper	--	33.0	--	3525	17.3	100	116	--	0.418
CM	La Oroya exp.	Blister to re-fined copper	--	18.0	--	200	--		4	--	0.013

Notes:

* 1976 energy figures are actuals, corresponding to about 211 x 10^3 MT copper production.

** Self-generated electricity refers to electricity generated by on-site fossil fueled equipment only (diesel, kerosene or residual fuel oil), where known. Self-produced hydroelectric power is not included.

EXHIBIT D-5 (continued)

Date/ Operator	Project	Remarks	Capacities 10^3 MT/Yr. Concentrates	Ref.Cu.	Energy Efficiencies Fuel 10^3Kcal/MT	Elect. kWh/MT	Electr. Max. load MW	Annual energy consumption with new plants at full capacity Self-gen.electr. %	Elec. 10^6kWh	Fossil 10^9Kcal	10^{15}joule
1978 CM	Cerro de Pasco	Expand concentrator to 7500 MT	350.0	--	--	--	3.0		24	--	0.086
CM	Casapalca	Expand concentrator to 2500 T	230.0	--	--	--	1.8		14	--	0.052
CM	San Expedito	Concentrator 850 T	300.0	--	--	--	0.7		6	--	0.020
1980 CM	La Oroya	Zinc expansion to 90000 MTPY	--	(20 zinc)	5000	--	3		20	100	0.491
CM	Cobriza	Expand concentrator to 12600T	350.0	--	--	--	21.0	100	168	--	0.605
CM	La Oroya	Lead agglomaration plant	--	--	--	--	2.4		19	--	0.069
CM	Cerro de Pasco	Water treatment plant	--	--	--	--	4.3		34	--	0.124
1981 MP	Cajamarquilla	Zinc electrorefining	--	(101 zinc)	--	4455	60.0		450	--	1.620
1982 MP	Cerro Verde II	Ore to elecwon copper	--	62.2	--	4710	43.6	100	293	--	1.055
CM	Orquídeas	Mine and concentrator, 100T	350.0	--	--	--	2.8	--	22	--	0.064

EXHIBIT D-5 (continued)

Date/ Operator	Project	Remarks	Capacities 10^3 MT/Yr. Concentrates	Ref.Cu.	Energy Efficiencies Fuel 10^3Kcal/MT	Elect. kWh/MT	Electr. Max. load MW	Annual energy consumption with new plants at full capacity Self-gen.electr. %	Elec. 10^6kWh	Fossil 10^9Kcal	10^{15}Joules
CM	La Oroya	Anode residue treatment	--	--	--	--	1.0		8	--	0.029
1983 MP	Ilo II	Blister to electrowon copper	--	150.0	860	400	7.5	100	60	129	0.756
MP	Tintaya	Ore to concentrates	80.0	--	--	1000	12.0	100	80	--	0.288
MP	Michiquillay	Ore to concentrates	400.0	--	--	675	40.0	100	270	--	0.972
CM	Cerro de Pasco	Concentrator expansion to 10,000 T	875.0	--	--	--	8.8		70	--	0.252
CM	La Oroya	Copper expansion	--	15.0	6700	--	6.5		45	101	0.583
CM	Montearosas De Ica	Mine/concentrator 2000 T	700.0	--	--	--	5.5	--	44	--	0.158
1984 CM	Toromocho	Multimetal complex, 15000 T	--	--	--	--	22.5	--	180	--	0.648
CM	Pacos Matagente	Pilot plant 30T	--	--	--	--	0.2	--	2	--	0.006
1985 CM	Orquideas	Expansion to 2000 T	350.0	--	--	--	2.8	--	22	--	0.064
CM	La Oroya	Zinc expansion	--	(180 zinc)	5000	--	27.7	--	222	900	4.565

EXHIBIT D-5 (continued)

Date/ Operator	Project	Remarks	Capacities 10^3 MT/Yr. Concentrates	Ref.Cu.	Energy Efficiencies Fuel 10^3Kcal/MT	Elect. kWh/MT	Annual energy consumption with new plants at full capacity Electr. Max. load MW	Self-gen.electr. %	Elec. 10^6kWh	Fossil 10^9Kcal	10^{15}Joules
MP	Quellaveco	Ore to concentrates	200.0	--	--	860	26.4	100	176	--	0.634
MP	Antamina	Ore to concentrates	cu 330 / zn 130	99.0 cu (59 zinc)		850	48.0	0	290	--	1.044
By 1985											
CM	All locations	Minor projects	--	--	--	--	7.0	--	56	--	0.202
By 1985	Existing plants	To high capacity	--	--	--	--	--	--	356	210	2.159
1985 Totals***				907.2					5120	P7415 C 378	51.014
1986 CM	Cobriza	Expansion to 17600 T, plus roasting on site					35.0				
1986 CM	Casapalca	Expansion to 7500 T					2.1				
1989 CM	Toromocho	Expansion by 15000 T					22.5				
1990 CM	Pacos Matagente	New plant					5.0				
1990 CM	La Oroya	Zinc ferrite plant					2.0				

*** Potential for switching from petroleum-based fuels to coal is not recognized in these energy projections. Also, transportation fuel use excluded in 1985 figures.

EXHIBIT D-5 continued

Date/ Operator	Project	Remarks	Capacities 10^3 MT/Yr. Concentrates	Ref.Cu.	Energy Efficiencies Fuel 10^3 Kcal/MT	Elect. kWh/MT	Annual energy consumption with new plants at full capacity Electr. Max. load MW	Self-gen.electr. %	Elec. 10^6 kWh	Fossil 10^9 Kcal	10^{15} joules
By 2000											
CM	Toromocho	Further expansion					--				
CM	Pucara	Smelting/refining copper					--				
CM	Pucara	Anode residue treatment					--				
CM	Pucara	Expansion smelting/refining					50.0				
1985 to 2000		"Accountable" energy					116.6		933	--	3.358
2000 Totals	(see continuation of Exhibit D-5)										

EXHIBIT D-5 (continued)

SUMMARY OF ENERGY DEMAND PROJECTIONS

10^{15} joules/year

	Electricity	Oil fuel for process uses	Total process uses	Oil fuel for transportation	Subtotal oil fuel	Coal/Coke	Totals
1976	7.05	13.13	20.18	7.11	20.24	1.58	28.87
Additional (2)	11.38	17.89	29.27				
1985	18.43	31.02	49.45	17.37 (1)	48.39	1.58	68.40
Additional (3)	15.84	23.77	39.61				
2000	34.27	54.79	89.06	31.29 (1)	86.08	3.16 (4)	123.51

Notes

(1) Transportation maintained at 26% of process energy consumption.
(2) Based on announced projects.
(3) Based on process energy growth of 4% p.a. in the period 1985-2000, with the split between electricity and oil fuels being 40/60, the same as for announced projects 1976-1985.
(4) Assumes doubling of coke use in lead smelting operations.

E. IRON AND STEEL

E-1 Introduction

The iron and steel industry subsector consists primarily of the following elements (Exhibit E-1):

(1) Iron ore mines at Marcona, near Nazca, operated since 1975 by Hierro Peru, and associated blast furnace charge stock production (sinter, pellets, etc.). Total capacity of about 10.7 million MT per year:

Pellets	4.0
Slurries	2.0
Sinter and concentrates	4.7 million MT
	10.7 million MT

(2) Blast furnaces and steel production facilities at Chimbote, operated by Siderperu, with a current capacity of about 520,000 MT per year of liquid steel.

In addition to these basic plants, there are casting shops and rolling mills at Chimbote, and there are two private steel rolling mills (Aceros Arequipa, Aceros Peruanos) which buy steel billets from Siderperu. A number of other private companies produce a range of products such as grinding balls and welded steel pipes.

E-2 Existing and Planned Production Facilities

The iron ore mines at Marcona have not operated at full capacity for several years. In 1976, for example, total production of ore and related products was equivalent to about 57% of available capacity, although the levels of production improved significantly in 1977. Associated with the mines are plants for the preparation of blast furnace chargestock, including sintering and pelletizing plants. In some areas the plants are obsolete, but, due to major expansions of iron ore exporting capacity in Brazil and Australia and the generally weak state of the market for iron ore, there appears little incentive for major modernization or expansion. Because of environmental considerations, it may be necessary to construct a third pelletizing plant to produce pellets with a sulfur content under 0.17% for export markets. Apparently there is an indefinite long range plan to install a direct reduction plant near Marcona to make sponge iron (no date available).

The steel complex at Chimbote consists of an iron-making plant, a steel plant, and casting shops and rolling mills. The iron-making plant is equipped with a single blast furnace (5 meter diameter hearth, 27 meters high) whose annual production capacity is about 300,000 MT. Part of the blast furnace production is cast into pig iron and the rest is transported in the liquid state to the steel plant. The blast furnace slag is quenched with water and then part is sent to the Cementos Pacasmayo plant and the remainder dumped (the amount used for making slag cement is not known). It is believed that approximately 600,000 MT of slag is available annually, and this could represent a major energy saving if fully utilized for cement manufacture.

The steel plant is equipped with two 30 ton electric furnaces, with a total production capacity of 190,000 MT. The plant also has two oxygen-blown converters which have a production capacity of 30 tons per casting and 330,000 MT per year. The raw steel is cast into ingots of 0.75, 5 or 7 tons, or is poured into a continuous casting machine to produce billets.

While most of the main inputs to the steel complex are produced in Peru, the most expensive item - coke - is imported:

	Coke Imports, MT	Total Value, US $million
1970	140,130	7.15
1971	120,000	6.12
1972	112,034	5.71
1973	143,320	7.31
1974	191,474	17.94
1975	193,443	18.12
1976 (1st half)	140,000	13.11
1976 (est.)	219,400	20.55

Following the completion of the expansion plants indicated below, over 1 million metric tons of coke will be required. As this could represent a foreign exchange requirement of about $100 million at present prices, plans call for the installation of a coke plant at Chimbote to utilize domestic coking coal from Oyon in combination with imported coking coal.

The current annual capacity of the Chimbote plant is approximately 520,000 MT of raw steel, of which 330,000 is from the oxygen converters and 190,000 from the electric furnaces. Charge to the electric furnaces consists of about 60,000 MT of in-house scrap and the balance is either domestic or imported scrap. It is planned to expand the complex to a total capacity of 2 million MT per year by the mid-1980's. Included in the expansion plans are improved port facilities, an oxygen plant, coke and sinter plants, a second blast furnace and converter, and two rolling mills. A second expansion phase, now expected in the mid-1990's, would raise liquid steel capacity to 4 million MT per year with the installation of a third blast furnace and converter, two continuous rolling mills and a plate mill. The expansions are required to cover domestic needs, which amount to about 1.25 million MT at present and are projected to reach 4 million MT by the year 2000.

Nominal capacities of the major plants to be added in the expansion phases are as follows:

	Total Capacity Million MT per Year
Coking	1.95 (0.65 Phase I)
Blast furnaces (two 11 metre dia.)	3.97
Steel converters (three 175 T each, plus three continuous casting lines)	3.5

Electric energy will be supplied by the Huallanca-Chimbote-Trujillo system, which is coupled to a hydroelectric plant of 100 MW (at Huallanca) and two thermal stations, one at Trujillo of 20 MW and the other at Chimbote (3 gas turbine units of 20 MW each). Electroperu plans to expand Huallanca to 150 MW and interconnect Chimbote with the electrical distribution system of central Peru. In addition, it is planned to install a thermal generating station at Chimbote to utilize blast furnace and coke oven gas. The capacity of this generating system will start around 60 MW in the mid-1980's (as soon as the coke plant is commissioned) and eventually reach 200 MW by 2000, after the commissioning of the final expansion:

	kWh	MW
1983 approx.	533	61
1985	723	82
1986	786	90
1987	848	97
1988	873	100
1989	898	102
1990	972	111
2000	1728	197

A further interesting development is the new prereduction plant for iron pellets, which is to be brought on-line at Chimbote in 1979. The construction of this plant follows trials with a small pilot plant (10 tons/day) which has proven very successful. The Lurgi-designed plant will use 90,000 MT per year of anthracite (from Alta Chicama) to produce 120,000 MT per year of prereduced pellets for the existing electric furnaces. In this way, imports of scrap can be cut while maintaining steel production at maximum levels.

Preliminary feasibility studies have been performed for the construction of a major integrated steel mill at Nazca, close to the Marcona mines. The first stage of the Nazca complex would produce 2 million tons of liquid steel per year, and the second stage would double that production. The iron ore would come from the Marcona mines, and coke would be made at Nazca itself, possibly from the deposits of coking quality coal at Oyon. The first studies indicated that pig iron would be produced in a single blast furnace of 11 meters hearth diameter, and steel in two 200 ton basic oxygen furnaces. Continuous casting will probably be included. In view of the delays in the plans for expanding Chimbote, and the fact that the proposed capacity of 4 million tons per year will probably meet demand in 2000, there appears little likelihood that construction of the Nazca plant will be initiated before the late 1990's, or that it will be commissioned prior to 2000.

E-3 Activity Data

The major operations of Hierro Peru may be summarized as follows:

	1976 10^6 Dry Long Tons	%	1977 10^6 Dry Long Tons	%
Sinter				
Installed capacity	2.700	100	2.700	100
Production	1.419	53	2.379	88
Pellets				
Installed capacity	3.500	100	3.500	100
Production	2.303	66	2.492	71
Slurry/Filter Cake Production	.979	-	1.222	-
Total Production	4.701	-	6.093	-

Major activity figures for the Chimbote iron and steel complex are as follows (thousand metric tons):

	1970	1971	1972	1973	1974	1975	1976
Input							
Pellets	122.0	219.4	249.4	372.6	449.3	443.7	425 (est)
Coke	52.8	120.1	111.1	128.2	164.7	162.4	155 (est)
Limestone	21.1	40.1	37.4	60.7	78.3	71.5	NA
Manganese	2.8	9.0	6.7	8.9	10.0	1.4	NA
Fluorite	-	0.6	0.5	1.2	2.1	1.1	NA
Total Steel Products	154.0	207.0	298.0	360.0	363.0	343.0	360.0

E-4 Current Energy Consumption and Energy Efficiency of Existing Plants

The energy consumed in the mining of iron ore is included in the non-ferrous sector, as most of the activity and energy data are collected and published as part of the mining sector.

Energy consumption in the integrated steel complex at Chimbote is summarized in Exhibit E-2. Primary energy sources for steel-making are coke and electricity, and petroleum products are injected into the blast furnaces and used as fuel for soaking pits, reheat and annealing furnaces.

Blast furnace oil consumption is estimated at 15 Kg. per MT of pig iron, say 4500 MT (33,000 bbls) hydrocarbons per year. Other uses for petroleum fuels are for various furnaces. In 1976, total petroleum use was 272,900 bbls., which indicates a consumption of about 240,000 bbls. for furnace fuels. Over the period 1972 to 1977, petroleum fuel usage has apparently risen from 0.67 to 0.83 barrels per MT of steel products, which may be explained by changes in the spectrum of products made, substitution of petroleum for coke in the blast furnace, etc. For energy balance purposes, it will be assumed that the most recent figure of 0.83 is appropriate for 1985 and 2000, while the actual figure of 0.80 will be used for 1976. Note that these figures are assumed to include all petroleum fuels used in processing operations (although not for electricity generation of any kind). The coke usage amounts to about 200,000 MT per year, equivalent to a coke rate of about 610 Kg per ton of pig iron, although a figure of 500 Kg. was quoted by Siderperu during discussions. Coke rates for several countries are shown below, indicating that the level achieved by Siderperu is representative of good modern practice:

	per MT Hot Metal	
	Coke equivalent of coke, fuel oil, and natural gas, kg	Actual coke injection kg
Belgium (1974)	641	591
France (1973)	621	540
Germany (1974)	581	502
Italy (1974)	545	489
Netherlands (1973)	569	467
UK (1974)	589	562
US (1974)	654	612

Source Gordian Associates Inc., "The Steel Industry" CCMS/NATO 47, 1977.

Electricity consumption figures for the period 1972 through 1990 (estimates for 1978 onwards) were provided by Siderperu. The historical electricity consumption per ton of steel products has fluctuated to a small degree from year to year. The average consumption is 590 kWh per MT and this figure will be used for the projections made in this study. At present, all electricity is provided by hydroelectric generation.

As shown in exhibit E-2, energy consumption by the steel complex at Chimbote amounted to 8.6 x 10^{15} joules in 1976. Specific energy consumption was 23.8 joules per metric ton of steel products, equivalent to about 19 joules per metric ton of liquid steel. In terms of typical steel industry figures, these appear to be well up to normal standards,* as the following figures (although not strictly comparable) will indicate:

		GJ per MT Liquid Steel
Peru -	through to semi-finished steel products (1976)	19.2
US -	to raw steel only (1974)	20.5
Netherlands -	to raw steel only (1973)	16.7
Italy -	to raw steel only (1974)	12.8
Germany -	to raw steel only (1974)	14.5
France -	to raw steel only (1973)	18.4

E-5 Energy Efficiency of New Projects

Data provided by Siderperu on historical operations and specific new projects was used to develop the total energy consumption projections shown in Exhibit E-3. Detailed energy efficiency data was not provided, but it is reasonable to assume that the best modern practice will be followed in all new designs. It is interesting to note that the use of prereduced pellets to displace scrap will increase the energy consumption of the steel industry due to the need to use coal/coke as a reducing reactant, while reducing the imports of scrap and thereby improving the national balance of payment situation (provided coal imports do not offset all the gains on scrap imports).

E-6 Projected Energy Consumptions

Using the data on existing and projected plants provided by Siderperu, Exhibit E-3 was developed. The exhibit includes information on electricty and fossil fuel consumptions and estimated on-stream dates.

It should also be noted that the energy data corresponds to specified production rates of liquid steel: the figure for 1976 is derived from the reported production for all steel products of 360,000 MT, while the figures for subsequent years assume full capacity operation soon after the previously mentioned expansions have taken place.

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* Gordian Associates Inc., "The Steel Industry, NATO/CCMS Study, report No. 47 (1977).

Assuming the plants operate at the capacities indicated, the total energy consumption is projected to rise to 22 x 10^{15} joules per year by 1985, and 80 x 10^{15} joules per year by 2000, increases of 260% and 940% respectively over base year 1976.

EXHIBIT E-1

LOCATION OF IRON AND STEEL FACILITIES

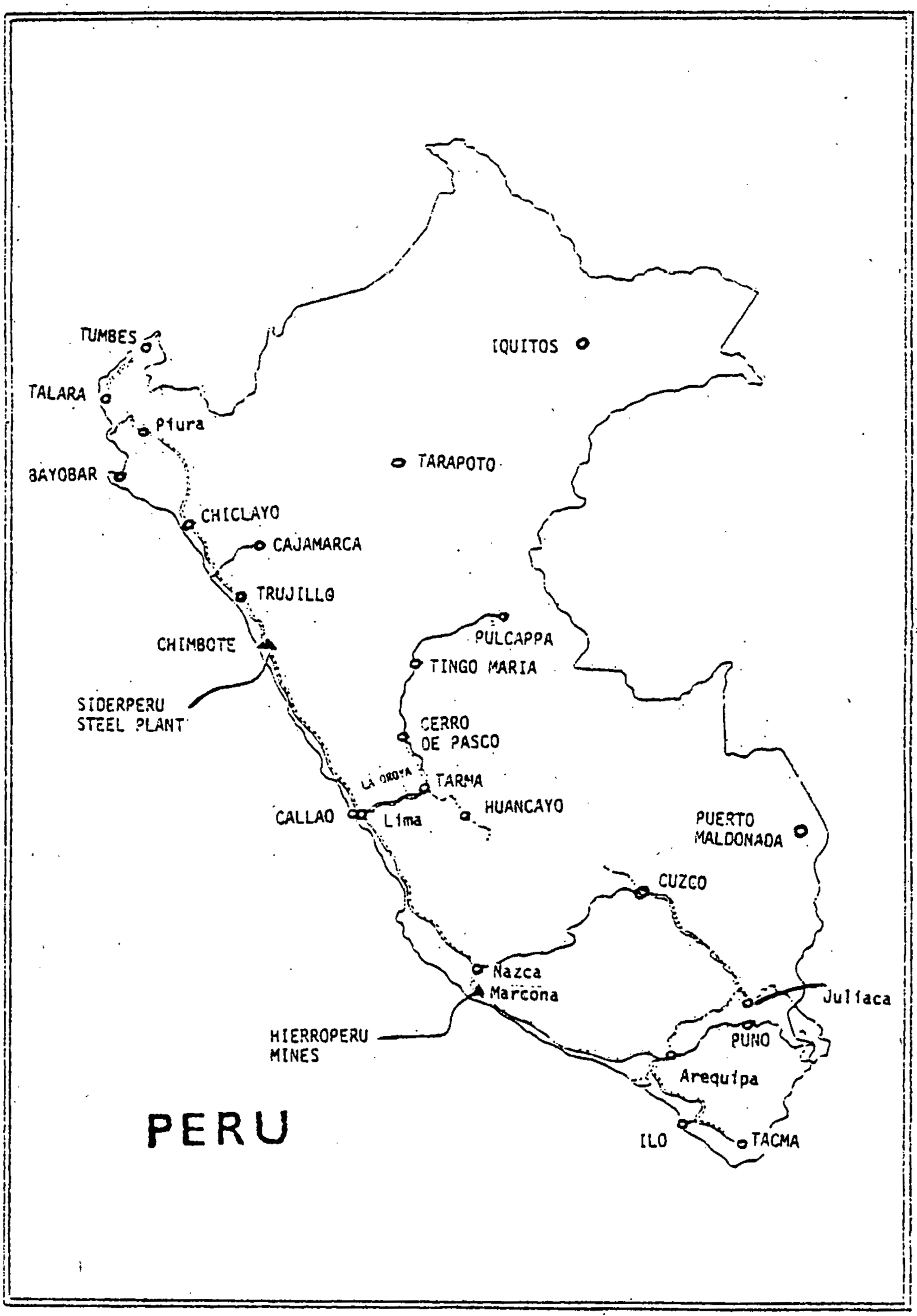

EXHIBIT E-2

ENERGY CONSUMPTION IN THE STEEL SECTOR, 1976

	Basic Units	10^{15} joules
Electricity		
10^6 kWh*	201.206	0.724
Fossil Fuels		
petroleum, bbls.	272,900	1.809
coke, tons	200,000	6.042
		8.575

Specific Energy Consumption

$$\frac{8.575 \times 10^{15}}{360{,}000}$$ = 23.8 gigajoules per MT steel products

19.2 gigajoules per MT liquid steel

* All electricity provided by hydroelectric generation.

EXHIBIT E-3

PROJECTED ENERGY CONSUMPTIONS FOR STEEL MAKING

All consumptions on an annual basis

	Production	Electricity*		Coal and Coke		Petroleum		Total Energy
	MT Liquid Steel	10^6 kWh	10^{15}J	MT	10^{15}J	bbls	10^{15}J	10^{15}J
1976 Energy Use	445,000	201.206	0.724	200,000	6.042	272,900	1.809	8.575
Existing plants at full capacity	520,000	236.000	0.850	233,700	7.060	332,000	2.201	10.111
1979 - Prereduction Plant		9.800	-	90,000	2.720	-	-	2.720
1985 - Stage I Expansion complete, plant operating at half capacity	incremental 480,000	217.850	0.785	215,700	6.516	306,500	2.032	9.333
1985 Energy Use	1,000,000	463.650	1.669	539,400	16.296	638,500	4.233	22.164
2000 - Stage 2 complete, plant at full capacity	incremental 3,000,000	1361.500	4.901	1,348,300	40.732	1,915,400	12.698	58.331
2000 Energy Use	4,000,000	1825.150	6.570	1,887,700	57.028	2,553,900	16.931	80.495

Specific Energies

1976 $\frac{8.575 \times 10^6}{445,000}$ = 19.2 GJ per MT liquid steel

1985 $\frac{22.164 \times 10^6}{1,000,000}$ = 22.2

2000 $\frac{80.495 \times 10^6}{4,000,000}$ = 20.1

F. CEMENT

F-1 Introduction

The cement industry in Peru consists of five companies, all of which are owned by the government. The plants are distributed throughout the country (Exhibit F-1). Almost all production is grey portland cement, and the value of this production is approximately 1% of all manufacturing industry. The main raw materials are obtained locally and the six plants are all located close to limestone deposits.

Local demand follows closely the fortunes of the construction industry. Some cement has been exported historically to Ecuador and sometimes to Chile and it appears that exports are now being directed to Ecuador, Bolivia and the United States. Imports are generally small, usually of white cement or special grades of portland cement not produced locally.

F-2 Existing and Planned Production Facilities

Of the five existing companies, all operate dry process plants and Cementos Lima operates a wet process plant at Chicla. The companies are as follows:

Cementos Lima is the oldest operation and continues to be the biggest, supplying the Lima, Ancash and Ica areas. The newest plant at Atocongo (replacing a nearby plant) was installed in 1969-1970, principally with German equipment. The single 85 meter dry process kiln has a four-stage Polysius preheater. Cementos Lima also operates a small wet process plant at Chicla, south of Lima, and the total installed capacity of the plants is 1.15 million tons per year. The main source of demand for cement is expected to continue to be the Lima area and therefore there is a possibility of expanding the Atocongo plant to 2 million MT per year by the early 1980's. The plot area of the existing plant allows for a parallel preheater kiln and two new grinding mills, one for raw mix and the other for clinker. The Atocongo plant produces both Type I and IP Cements. The IP contains 10 to 15% locally-mined pozzolan, and is used in the local market. Up to 40% of plant production appears likely to be exported in the near term.

Cementos Andino, located near Tarma in the central Sierra, supplies a wide area, including Iquitos via the central highway to Pucallpa and then down river by barge. The plant was installed in 1958 and was expanded in 1962 to a total capacity of 440,000 MT per year. Minor revamping of the plant is scheduled for 1980 to increase consumption to 540,000 MT per year.

Cemento Pacasmayo supplies the north of Peru. Demand is expected to grow significantly in this area and a big expansion plan has been carried out. Installed capacity of this plant, built in 1957, was originally 380,000 MT per year. Capacity was expanded to 1 million MT per year late in 1977. It is important to note that this plant is supplied with blast furnace slag from the Chimbote steel complex for intergrinding with clinker to form a slag cement. Quantities of slag utilized are not known, but the production of a blended cement can reduce significantly the energy needs for construction.

Cemento Yura (near Arequipa) and Cemento Sur at Juliaca supply the south of Peru. The Yura plant was commissioned in 1968 with a capacity of 150,000 MT per year, and the Juliaca plant was installed in the early 1950's with a capacity of 90,000 MT per year. The demand for cement in the Arequipa area is such that there are plans to expand the capacity of the Yura plant to 480,000 MT per year by the end of 1978, although full production is not expected before about 1983.

The capacity of plants is summarized in Exhibit F-2.

F-3 Activity Data

Current portland cement production is almost 2 million MT per year:

		million MT per year	
1970		1.144	
1971		1.466	
1972		1.620	
1973		1.726	
1974		1.919	
1975		1.950	
1976		1.970	
	Cementos Lima		0.950
	Cementos Andino		0.445
	Cemento Pacasmayo		0.320
	Cemento Sur		0.090
	Cemento Yura		0.165
			1.970
1977			1.968

F-4 Current Energy Consumption

During 1976, the cement industry used about 1.57 million barrels of petroleum fuels, of which 89.2% (1.4 million bbl) was used as the kiln fuel and 10.8% (0.17 million bbl.) for electricity generation. Plants with their own power plants are as follows:

	Petroleum fuels for electricity generation
Cemento Pacasmayo	109,600
Cemento Sur (Juliaca)	48,300
Cemento Andino (Tarma)	11,900
	169,800 bbls

(Source: Incitemi report)

The efficiency of electrical generation is reported in the Anuario Estadistica Electrica 1975 as follows:

	10^6 kWh	Diesel 10^6 gal	Residual 10^6 gal	kWh/gallon
C. Pacasmayo	39.782	0.077	4.528	9.02
C. Sur	10.992	-	2.027	5.67
C. Andino	6.487	0.357	0.142	12.97

All kiln fuel in Peru is provided by petroleum products. In summary, therefore, fuel use appears to be as follows:

thousands of barrels

	1974	1975	kilns	elec gen	1976 Total	1977 est.	1978 est.
Pacasmayo	315	318	250	110	360	350	370
Andino, Lima	821	899	961	12	973	980	990
Sur, Yura	198	244	196	48	244	242	245
	1334	1561	1407	170	1577	1572	1605

The Atocongo plant of Cementos Lima was visited and kiln energy efficiency is about 750 kcal/kg. under the best circumstances, and up to 780-800 kcal/kg. as a long term average. Electricity consumption (including all plant, office and warehouse uses) is about 110 to 120 Kwh/tonne of cement. Based on this information, an estimate of the energy efficiency of the Cementos Andino plant can be made, by difference, from the Incitemi totals. Overall energy use for 1976 for the cement industry is summarized as Exhibit F-3.

F-5 Energy Efficiency of Existing Plants

Based on the data given above, and assuming that an average of 5% gypsum is added to clinker to make cement, and that self-generating efficiency is unchanged for 1976, efficiencies may be estimated and compared to European and US practice for dry process plants as follows:

	Kiln fuel kCal/Kg Cement	Electricity kWh/MT Clinker
(1) Lima	900	115
(2) Andino	1440	NA
Pacasmayo	1215	137
Sur		135
	1196	
Yura		NA
Peru Average	1111	137
(3) Fed. Republic of Germany	800-1200	118
(3) Italy	900	127
(3) UK	886	127
(3) US	1358	163

Notes
(1) Includes Chicla plant.
(2) By difference.
(3) Gordian Associates Inc. "The Cement Industry" NATO/ CCMS 46, 1976 (Data for 1974).

The calculation of efficiency for the Pacasmayo plant does not take into account any effect from the incorporation of blast furnace slag in the final product cement. An unknown quantity of water-quenched granulated slag is shipped from Chimbote to Pacasmayo for the manufacture of a blended cement.

These figures indicate that the cement industry in Peru is operating at an efficiency level close to normal international standards.

F-6 Energy Efficiency for New Projects

Any new plants would presumably be designed to the highest modern standards of efficiency and would therefore use conventional suspension preheater technology. While long term operating energy efficiency will depend on such factors as raw material quality and variability, fuel quality and variability, steadiness of operation and product specifications, it is reasonable to assume the following as representative of best modern practice:

kiln fuel 790 kcal Kg cement

electricity 120 kWh MT clinker (114 per MT cement)

The amount of fuel required for self generation will of course depend on the specific plant design chosen for new plants. For projection purposes, an average of 25% of new electricity needs may be assumed.

F-7 Projected Energy Consumption

On the basis of new plant capacity being installed as described earlier in this section and on a 5% growth rate after 1985, estimates of future energy needs for the cement industry have been made (Exhibit F-4). A plant operating factor of 90% is assumed. In summary, it is projected that energy consumption for this subsector of industry could rise to about 32×10^{15} joules. Note that no specific fuel mix is projected. While current operations rely entirely on petroleum-based fuel, there is apparently no technical reason (unless there are alkali problems) why all kiln fuel should not be in the form of coal, depending only on the economics of coal use and its availability at the cement plants.

It is important to note that the energy projections do not take into account the potential for energy savings by the production of blended cements, utilizing slag from the steel plant at Chimbote (as is done already to some extent at Pacasmayo) or possibly naturally-occuring volcanic ashes (pozzolans) which may exist in the Arequipa area.

EXHIBIT F-1

LOCATION OF CEMENT PLANTS

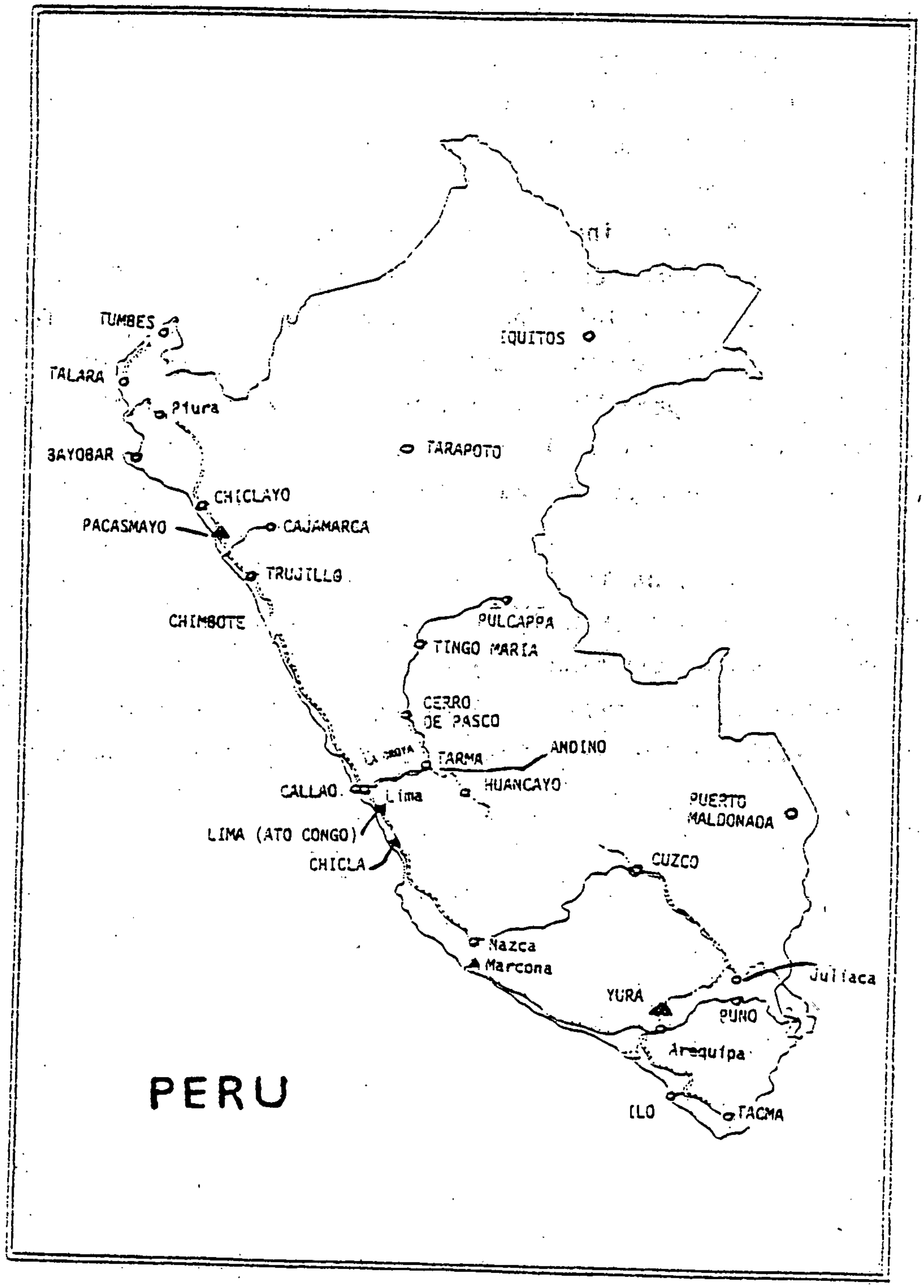

EXHIBIT F-2

CEMENT PLANT CAPACITIES

Plants*	Date Built	Nominal Capacity Million MT per Year	Planned Capacity Million MT per Year	Date
Cementos Lima				
Atocongo	1970	1.00	2.0	1983 est.
Chilca	-	0.15	0.15	-
Cementos Andino	1958/62	0.44	0.54	1980
Cementos Pascasmayo	1957	0.38	1.0	1977
Cemento Yura	1968	0.15	0.48	1979
Cemento Sur	1963	0.09	0.09	-
		2.21	4.26	by about 1983

*All plants dry process except Chicla (wet-process).

EXHIBIT F-3

SUMMARY OF ESTIMATED ENERGY USE IN THE CEMENT INDUSTRY, 1976

Company	10^6 MT Cement	Kiln Fuel Used: bbls	Kiln Fuel Used: K cal per Kg cement	Kiln Fuel Used: 10^{12} K cal	Kiln Fuel Used: 10^{15} Joules	Electricity: KWH per MT clinker	Electricity: % self generated	Electricity: 10^6 KWH	Electricity: 10^{15} Joules	Total Energy 10^{15} Joules
Lima	0.950	961,000	900	0.855	3.578	115	0	103.8	0.374	3.952
Andino	0.445		1440	0.640	2.679	137	11.3	57.9	0.208	2.887
Pacasmayo	0.320	250,000	1215	0.389	1.628	137	100	42.5	0.150	1.778
Sur	0.090	196,000	1196	0.108	0.452	135	100	11.4	0.041	0.493
Yura	0.165		1196	0.197	0.825	137	0	21.5	0.077	0.902
Totals	1.970	1,407,000	1111	2.189	9.162	120	25.5	237.1	0.850	10.012

EXHIBIT F-4

PROJECTED ENERGY CONSUMPTION IN THE CEMENT INDUSTRY, 1985 - 2000

	Production	Kiln Fuel		Electricity		Total Energy
	10^6 MT/yr	10^{12} K cal	10^{15} joules	10^6 KWH	10^{15} joules	10^{15} joules
1976	1.97	2.189	9.162	237.1	0.850	10.012
Existing plants at full capacity	2.21	2.456	10.278	288.2	1.038	11.316
Lima (Atocongo)	1.00	0.790	3.307	114.0	0.410	3.717
Andino	0.10	0.079	0.331	11.4	0.041	0.372
Pacasmayo	0.62	0.490	2.051	70.7	0.254	2.304
Yura	0.33	0.261	1.091	37.6	0.135	1.226
At full capacity	4.26	4.076	17.058	521.9	1.878	18.936
1985, all plants at 90%	3.83	3.668	15.352	469.7	1.690	17.042
Assuming 5% annual growth rate, and full capacity operation*						
"Existing" plants	4.26	4.076	17.058	521.9	1.878	18.936
Incremental	4.59	3.626	15.175	523.2	1.883	17.058
At full capacity	8.85	7.702	32.233	1045.1	3.761	35.994
2000, all plants at 90%	7.96	6.932	29.010	940.6	3.385	32.394

*Incitemi report uses 5% growth rate.

G. OIL REFINING

G-1 Introduction

The oil refining subsector of industry has taken on increasing importance as the oil resources of Peru have been developed. There are at present six refineries in Peru, Exhibit G-1, although one (Conchan) is not currently in operation. Total crude distillation capacity is 180,000 barrels per day, and there are tentative plans for a new refinery, possibly to be associated with the Bayovar petrochemical complex and to have a design capacity in the range of 70 to 100,000 BPD. This refinery would be commissioned in the mid-1980's.

Present domestic needs for oil products are estimated to be about 120,000 BPD. Domestic crude oil production is currently about 160,000 BPD. Historically, imports of crude have been mostly from Venezuela and Ecuador. For the near term future, it appears that domestic production wll satisfy demand, with a surplus of up to about 40,000 BPD through 1985, after which Peru may again become a net importer of crude.

G-2 Existing and Planned Processing Facilities

The existing plants are listed in Exhibit G-2. Capacities are expressed as barrels per stream day.

With respect to expansion of refining capacity, tentative plans were announced a year or two ago for a new refining complex at Bayovar, which would provide feedstock for the proposed petrochemical complex. The refinery capacity was planned to be about 100,000 BPD, and process units would include crude distillation, vacuum distillation, catalytic reforming and merox treating. However, it now appears likely that the Bayovar complex will suffer extensive delays and modifications, and therefore refinery plans are now indefinite. It is most likely that a new refinery will be built, at an undetermined location, to process 70 to 100,000 BPD of crude. Start-up is not likely before 1986. The new refinery would probably include primary distillation, vacuum distillation, fluid cat. cracking, and platforming.

In addition to the new refinery, there are tentative plans for the addition of a visbreaker (16,000 BPD) at La Pampilla refinery. Start-up is expected to be 1982 to 1984.

G-3 Activity Data

Crude oil runs amounted to about 113,000 BPD in 1975:

	1975			
	Million Barrels			MBPD
	domestic	imports	total	total
Talara	21.854	3.463	25.317	63.36
La Pampilla	0.721	11.026	11.747	32.18
Conchan	-	2.873	2.873	7.87
Luis Diaz	0.377	0.138	0.515	1.41
Pucallpa	0.704	-	0.704	1.93
	23.656	17.500	41.156	112.76

The usual refinery products, from propane to residual fuel oil, are marketed: a range of motor gasolines is made, as are turbine fuels and distillate fuel oils. About 540,000 bbl. of lubricating oils were manufactured in 1975. Other major products included:

	1975 (bbls)
Greases	16,400
Solvents	143,300
Naphthenic acids	2,500
Asphalt	229,600

Because of a current imbalance of refinery products with market demands, there are some imports of products (e.g. 7000 BPD of diesel). Apparently, demand for LPG and diesel is high, while there is generally a surplus of gasoline. Some changes in operations are possible to alleviate the situation, such as changing catalyst in the FCC units and changing FCC conversion severity. Such changes are limited at Talara because of the constraints on FCC operations of providing propylene feedstock to the adjacent solvents plant and clarified oil as a feedstock to the carbon black plant.

G-4 Current Energy Consumption

Petroperu indicated that about 5000 BPD of crude oil (equivalent) is required for all internal company operations including that used to process about 120,000 BPD of crude, as well as for pipeline pumping operations. This fuel is consumed in the form of refinery gas, LPG, diesel, some kerosene and gasoline fractions, and heavy fuel oil. Some natural gas is also included in the figure.

With respect to natural gas, about 65 million SCFD is produced in association with the domestic crude. Its disposition for 1978 will be approximately as follows:

	MMSCFD
Feedstock for urea plant	7
Extraction operations of Petroperu	14
Fuel use in plants	25
Domestic/commercial uses in Talara, Negritos etc.	9
Lost to flare	10
	65

In fact, current losses to atmosphere are probably about 20 MMSCFD, of which 10 are economically recoverable: plans are being made for the commissioning of a gas recovery system.

G-5 Energy Efficiency of Existing Plants

Based on refinery fuel consumption figures for the Petroperu refineries at La Pampilla, Talara, Iquitos and Pucallpa, an average of 150 to 160,000 Btu per barrel of crude processed was estimated. For the type of plants operated by Petroperu, this may be a little higher than might be expected. A rough estimate based on energy consumption in modern process units suggests that the same combination of distillation capacity and secondary conversion units (FCC, platforming, etc.) could result in an energy consumption of about 115,000 Btu per bbl. crude:

		Energy Efficiency (fuels only)*
	MBPD Capacity	MMBtu/Bbl - Charge
Crude distillation	178.5	0.0870
Vacuum distillation	39.3	0.1133
FCC	23.6	(0.0283)
Unifiner	2.7	0.0677
Platformer	2.0	0.3800
Overall		0.115

* Gordian Associates Inc., "The Data Base: Potential Energy Conservation in Nine Selected Industries," June 1974 for the U.S. Federal Energy Administration.

Note, however that this estimate does not take into account the additional processing energy needed in the production of luboils, solvents, asphalt, etc. Luboil manufacture is particularly energy intensive. This fact, coupled with the effects that detailed changes in process configuration from unit to unit can have, could explain much of the difference between 115,000 and 160,000 Btu per bbl. In fact, our estimates of refining industry energy use for this study are based on 180,000 Btu per bbl., to allow for terminal and bulk distribution plant operations, in addition to the refineries themselves.

Finally, the following data were obtained for the refinery at La Pampilla:

	May 1978
Charge to primary distillation, barrels	1,640,500
Electricity used, 10^6 kWh	2.1941
* Electricity used, Btu equivalent	7488.5×10^6
Fuel used, bbls.	31,422
* Fuel used, Btu equivalent	$188,532 \times 10^6$
Total Btu (equivalent)	$196,021 \times 10^6$
Energy efficiency, Btu per bbl. charged	119,500

This energy efficiency suggests that the plant is operated well in accordance with good modern practice.

G-6 Energy Efficiency of New Projects

As noted above, the energy efficiency of plants will vary according to the details of the design, and this is influenced by the type of feedstock and the nature of the products required. Representative factors which may be used to estimate energy consumption for well operated plants, in the absence of specific design data, are as follows:

	Fuel MMBtu/bbl	Elec. kWh/bbl
Crude distillation	0.0870	0.42
Vacuum distillation	0.1133	0.75
Unifining	0.0677	1.05
Platforming	0.3800	3.23
FCC	(0.283)	2.67
Offsites	-	3.0

* At 3413 Btu/kWh and 6×10^6 Btu/bbl.

G-7 Projected Energy Consumption

In view of the somewhat indefinite plans for refinery expansion, it is difficult to project energy consumption in the oil refining sector with any degree of reliability. However, it is reasonable to assume that the existing plants will be operated at about the same level of efficiency at higher throughput as demand rises. After 1985, it may be assumed that a new refinery of 100,000 BPD will be constructed, with an energy efficiency corresponding to the best modern practice. Refinery energy consumption is therefore projected to total about 11 x 10^{15} joules by 1985 and about 18 x 10^{15} joules by 2000 (see Exhibit G-3).

OIL REFINERY LOCATIONS

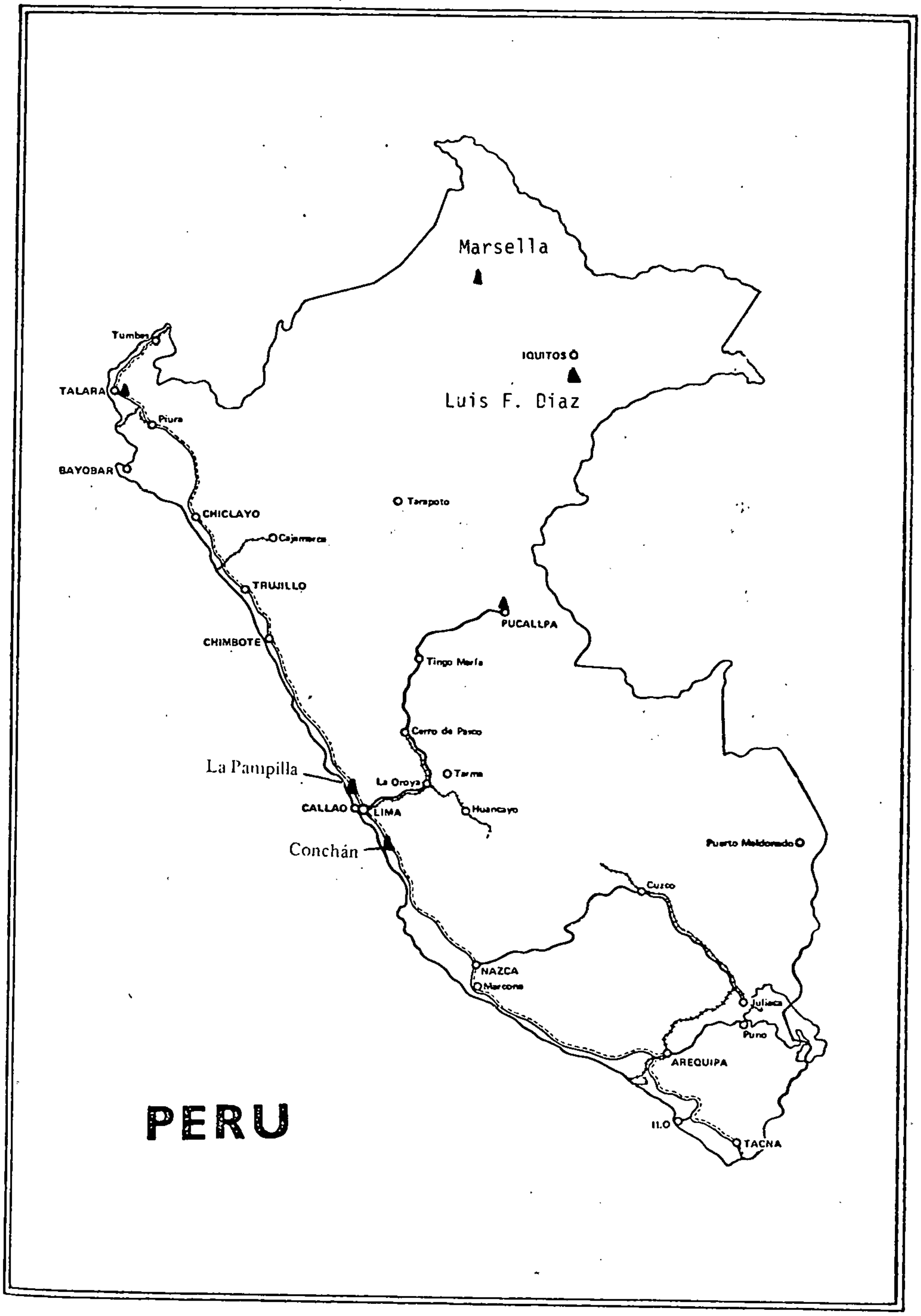

EXHIBIT G-2

REFINERY PROCESS UNIT CAPACITIES

Sources: (1) "Estadistica Petrolera del Peru, 1975", Min. de Energia y Minas, Boletin Oficial de la Direccion General de Hidrocarburos, Numero 26.
(2) The Andean Report, November 1977.
(3) Discussions with Petroperu.

(BPSD)	Talara	La Pampilla	Conchan[D]	Marsella	Luis Diaz	Pucallpa	Total
Crude Dist.	65,000	102,000 [C]	8,500	1,400	1,200	2,500	180,600
Vacuum Dist.	20,000	11,000	4,500				35,500
Cat. Cracking	16,600[A]	7,000[B]	-				23,600
Unifining	-	2,000	-				2,000
Platforming	-	2,000	-				2,000
Vac. dist. (luboil)	1,000	-	-				1,000
Vac. dist. (asphalt)	2,800	-	-				2,800
Other	-	13,000*	3,000**				16,000

* Merox treater for Kerosene
** Asphalt and solvents.
A Design capacity: normally does not exceed approximately 13,500 BPD.
B Design capacity: normally does not exceed about 5,500 BPD.
C New unit of 65000 BPD capacity brought on line in 1977.
D This plant now shut down.

EXHIBIT G-3

ESTIMATED ENERGY CONSUMPTIONS

Fuel 10^6 Btu per bbl	Elec. kWh per bbl	Process Units	1976 T'put 10^3 BPD	1976 Fuel 10^9 Btu/day	1976 Elec. 10^3 kWh/day	1985 T'put 10^3 BPD	1985 Fuel 10^9 Btu/d	1985 Elec. 10^3 kWh/d	2000 T'put 10^3 BPD	2000 Fuel 10^9 Btu/d	2000 Elec. 10^3 kWh/d
0.087	0.042	Crude dist	100.0	8.70	42.0	170.0	14.79	71.4	270.0	23.49	113.4
0.1133	0.75	Vac. dist	25.0	2.83	18.8	34.8	3.94	26.1	55.3	6.27	41.5
(0.283)	2.67	FCC	17.0	(4.81)	45.4	23.6	(6.68)	63.0	37.5	(10.61)	100.1
0.0677	1.05	Unifiner	2.0	0.14	2.1	2.7	0.18	2.8	5.0	0.34	5.3
0.380	3.23	Platformer	1.5	0.57	4.8	2.0	0.96	6.5	5.0	1.90	16.2
-	3.0	Offsites	100.0	-	300.0	170.0	-	510.0	270.0	-	810.0
SUBTOTALS				7.43	413.1		13.19	679.8		21.39	1086.5
* Luboil and other Units			-	9.00	-		15.30			23.50	-
				16.43	413.1		28.49	679.8		44.89	1086.5
TOTALS (10^{15} Joules per year)				6.07	0.52		10.45	0.86		16.57	1.37
				6.59			11.31			17.94	

* Rough estimate only: these figures assume fuel for on-site electricity generation included in total fuel.

H. PETROCHEMICALS

H-1 Introduction

A significant development within the industrial sector of Peru over the next few years is likely to be the construction of a range of petrochemical plants. Under Andean Pact agreements, various products have been assigned to Peru, some exclusively and others shared with specific countries. These include acrylonitrile, SBR latex, poly-butyl rubber, polyacrylonitrile, acrylic fibers, PVC emulsion grade, carbon black and isopropyl alcohol. Products which may be made in any Andean Pact Country include dichloroethane, VCM, phthalic anhydride, LDPE, polystyrene, suspension-grade PVC, and such basic compounds as ethylene, propylene, butylenes, butadiene, isoprene, xylenes, benzene and ethyl benzene.

To date, Peru has not had any significant production of basic petrochemicals. Ambitious plans for a major complex at Bayovar, to be provided with feedstocks by a new refinery at that site, were drawn up several years ago. In 1975, the total capital investment for the complex was projected at about $2.4 billion. It now appears most unlikely that this amount can be raised within the time frame originally proposed. There have been many delays and cutbacks in the scale of the Bayovar plans, and it seems that the olefins and derivatives plants will go ahead, with other downstream plants postponed indefinitely.

H-2 Existing and Planned Processing Facilities

The only major petrochemical plants currently in operation are both located at Talara (see Exhibit H-1). A carbon black plant, original capacity 7700 MT per year, uses a clarified oil from the refinery fluid cat. cracking unit as feedstock. This plant is to be expanded to 15000 MT per year in the near future. Most of the carbon black is sent to tire manufacturers, with some going to make inks, paints, records, and various miscellaneous rubber products.

A plant for manufacturing isopropyl alcohol utilizes propylene from the cat. cracking unit as feedstock. This plant has a capacity of 10,650 MT per year of IPA, with 5000 MT per year of acetone as a secondary product.

The previously-mentioned Bayovar complex was originally based on gas oil and naphtha feed from a new 100,000 BPD refinery, also to be built at the Bayovar site. It is not clear what feedstocks will be used for any units which are eventually built at Bayovar.

In addition to the Talara plants, several companies produce a range of solvents and aromatics in relatively small quantities.

H-3 Activity Data

No actual plant production data was obtained for Talara. As noted previously, carbon black capacity is 7700 MT per year, and solvents capacity is 16650 MT per year IPA and 5000 MT per year acetone. A total of about 12,000 MT of various organic solvents was produced in 1975 from a variety of small plants throughout Peru.

H-4 Current Energy Consumption and Energy Efficiency of Existing Plants

No actual plant energy consumption data was provided, and therefore no comments can be made on plant efficiency. However, on the basis of typical industry practice, estimates of current energy consumption have been made and are presented in Exhibit H-2.

H-5 Energy Efficiency of Proposed Plants

Since plans for new plants are indefinite, no comment can be made on energy efficiencies, except that any new plant will presumably be designed according to the best available technology at the time.

H-6 Projected Energy Consumption

Again, since no definite plans for new petrochemical plants have been made, forecasts of energy use can only be highly approximate. Energy requirements based on the construction of an ethylene plant (160,000 MT/year) and associated units at Bayovar are presented in Exhibit H-2.

EXHIBIT H-1

PETROCHEMICALS

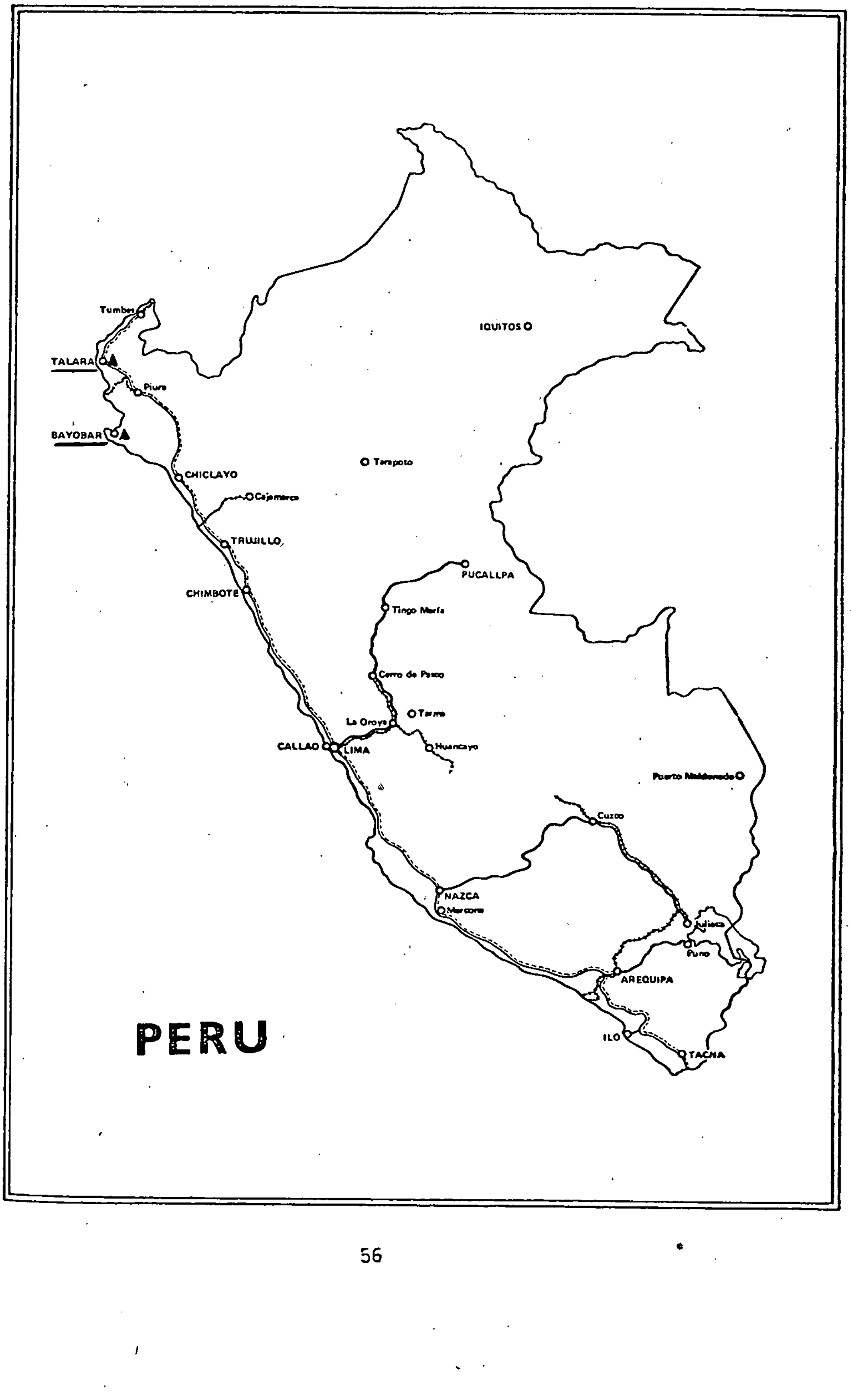

EXHIBIT H-2

ESTIMATES OF PETROCHEMICAL PLANT ENERGY CONSUMPTIONS THROUGH 2000

Date	Plant	Annual Capacity	Assumed Energy Efficiency	Fuel 10^{15} Joules	Electricity 10^{15} Joules	Total 10^{15} Joules
	Carbon black	7700 MT	13.9×10^9 J/MT	0.11	N/A	0.11
	IPA	10650 MT	13.1×10^9 J/MT	0.11	0.03	0.14
1976 Totals				0.22	0.03	0.25
By 1985	Carbon black exp.	By 7300 MT	13.9×10^9 J/MT	0.10	--	0.10
1985 Totals				0.32	0.03	0.35
After 1985	Integrated petro-chemical complex at Bayovar*					
	- ethylene	160,000 MT	35×10^9 J/MT	5.54	0.06	5.60
	- VCM	50,000 MT	13×10^9 J/MT	0.07	0.58	0.65
	- PVC	30,000 MT	15×10^9 J/MT	0.05	0.40	0.45
	- LDPE	20,000 MT	13×10^9 J/MT	0.10	0.16	0.26
	- Acrylonitrile	15,000 MT	15×10^9 J/MT	0.12	0.11	0.23
2000 Totals				6.20	1.34	7.54

* Rough estimates of plant size only.

I. CHEMICALS

I-1 Introduction

The subsector "chemicals" includes a large number of products, many of which are made in quite small quantities. About ten products represent 90% of the total production. These main products are:

acids	-	hydrochloric, nitric, sulfuric
alkalis	-	sodium hydroxide, ammonia
others	-	chlorine, sodium chloride, calcium carbide, calcium disulfide.

I-2 Existing and Planned Processing Facilities

The following brief descriptions of some of the main product areas will provide some basic data on the chemicals subsector. Key sites are indicated in Exhibit I-1. Unfortunately, time did not allow a comprehensive check to be made of the plant throughput and expansion plans described here; these must therefore be regarded as tentative.

The sulfuric acid is obtained as a byproduct from the mining sector and about 70,000 MT per year is manufactured at the Centromin La Oroya smelting sites. In fact, a major use for sulfuric acid is the processing of copper ores through leaching and electrowinning processing systems (such as at Cerro Verde). A major future demand for sulfuric acid will be for the Bayovar phosphate fertilizer plants. It appears that this demand will be met by the production of 176,000 MT per year of acid from the zinc smelter at Cajamarquilla (now under construction).

Sodium carbonate is not currently made in Peru but there is a project coordinated by Induperu to construct a plant near Lima in the early 1980's.

Caustic soda (sodium hydroxide) is produced at a rate of about 40,000 tons per year by Sociedad Paramonga and 30,000 tons per year by Quimica del Pacifico. Expansion of the latter plant to a production of about 50,000 MT per year is understood to be planned for completion by 1981.

Hydrochloric acid is produced at about 80,000 MT per year by Soc. Paramonga and Quimica del Pacifico. This represents about 15,000 MT spare capacity, and it is therefore unlikely that new plants will be built for many years.

Nitric acid production at the Cachimayo and Fertisa fertilizer plants is around 96,000 MT per year. Ammonia is also produced at these plants at a rate of about 32,000 tons per year. Energy requirements for these materials will be included in that for fertilizers.

About 63,000 MT per year of chlorine is produced in conjunction with caustic soda by Soc. Paramonga and Quimica del Pacifico not all of which is used.* Expansion of the Paramonga paper plant will include expansion of electrolysis plants and therefore there will be an additional surplus of chlorine. It is planned to expand the existing PVC plant, which uses alcohol from sugar fermentation as a feedstock as well as chlorine, from the current capacity of about 9,000 MT per year to 30,000 MT per year. Actual production of PVC (suspension grade) was about 7,500 MT in 1974 and in 1975.

Sodium chloride is produced from the salt deposits at Las Salinas on the coast north of Lima. Production is about 250,000 MT per year, which is estimated to be about 70% of full capacity. There are plans for brine deposits near Bayovar to be exploited in conjunction with the proposed phosphate fertilizer project: production of sodium chloride is planned to be 120,000 MT per year and of potassium chloride 100,000 MT per year. Further mention of this project is made in the fertilizer section of this report.

I-3 Activity Data

Details of production levels for the chemicals sector were not collected. However, approximate levels of production of some of the most important products have been indicated above.

I-4 Current Energy Consumption and Energy Efficiency of Existing Plants

No specific data on energy consumption or energy efficiency was available. However, using the approximate production data given previously for key products and assuming representative energy consumptions for these products, it was possible to develop a rough estimate of the energy requirements of this subsector. The estimate is summarized in Exhibit 1-2.

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* The production of Chlorine is stoichiometrically tied to the caustic production level, which is about 70,000 MT per year. However, while demand for caustic is strong, not all of the chlorine which is produced finds a market.

I-5 Energy Efficiency of New Projects, and Projected Energy Consumptions

Where available, energy data for specific projects was used for energy projections. Where such data was not available, estimates were based on typical industry practice. Projections for 1985 and 2000 are summarized in Exhibit I-3.

EXHIBIT I-1

CHEMICALS

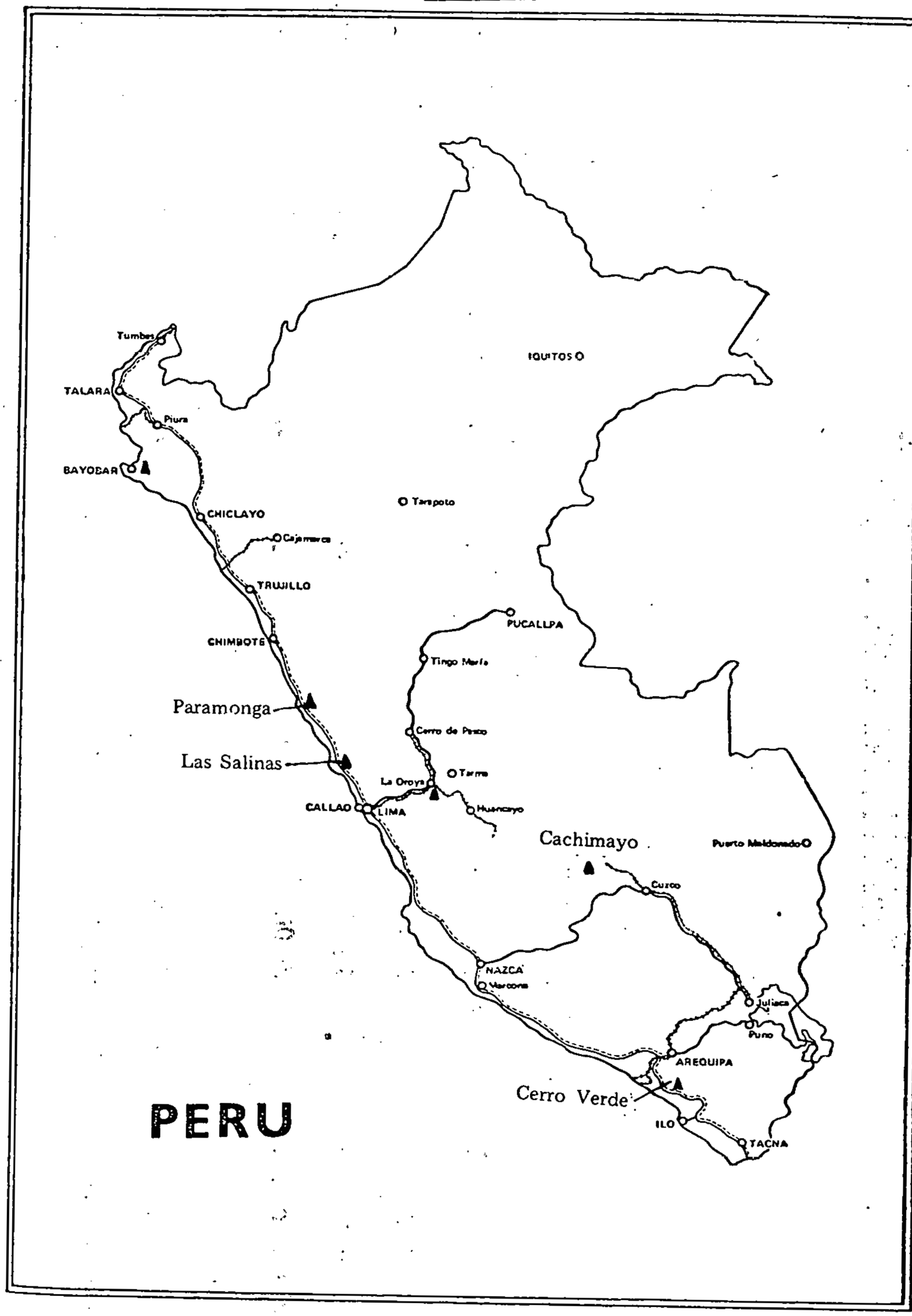

EXHIBIT I-2

ESTIMATE OF ENERGY CONSUMPTION FOR A MAJOR PART OF THE CHEMICALS SUBSECTOR, 1976

Item	Production Level Assumed MT Per Year	Energy Efficiency Fuel 10^9 J/MT	Energy Efficiency Elect. KWH/MT	Energy Consumed 10^{15} Joules Per Year Fuel	Energy Consumed 10^{15} Joules Per Year Electricity	Energy Consumed 10^{15} Joules Per Year Total
Sulfuric acid	70,000	--	11	--	--	--
Caustic soda	70,000	--	3700	--	0.93	0.93
Hydrochloric acid	60,000	9.9	99	0.60	0.02	0.62
Chlorine	63,000	--	*	--	*	*
PVC	7,500	4.0	530	0.03	0.01	0.04
Sodium chloride (salt)	250,000	3.6	55	0.90	0.05	0.95
				1.53	1.01	2.54

* Note that chlorine and caustic are produced simultaneously via electrolysis of brine. All of the electricity consumed in the process has been allocated to the primary product, caustic soda.

EXHIBIT 1-3

ENERGY CONSUMPTION PROJECTIONS, 1985 and 2000

	Item	Production level assumed MT per year	Energy Efficiency Fuel 10^9 J/MT	Energy Efficiency Elect. KWH/MT	Electric Energy Consumed 10^{15} joules per year	Fuels Consumed 10^{15} joules per year	Total Energy Consumed 10^{15} joules
By 1985							
	Sulfuric acid	250,000	--	11	0.010	--	0.010
	Sodium carbonate	70,000	12.0	--	0.104	0.840	0.944
	Caustic soda	90,000	--	3700	1.199	--	1.199
	Hydrochloric acid	80,000	9.9	99	0.029	0.792	0.821
	Chlorine	80,000	--	*	*	--	*
	PVC	20,000	4.0	530	0.038	0.080	0.118
	Sodium chloride(salt)	350,000	3.6	55	0.069	1.260	1.329
	Potassium chloride	20,000	3.6	55	0.004	1.072	1.076
					1.453	4.044	5.497
By 2000							
	Sulfuric acid	500,000	--	11	0.020	--	0.020
	Sodium carbonate	100,000	--	--	0.149	1.200	1.349
	Caustic soda	180,000	--	3700	2.398	--	2.398
	Hydrochloric acid	120,000	9.9	99	0.044	1.188	1.232
	Chlorine	160,000	--	*	*	--	*
	PVC	30,000	4.0	530	0.057	0.120	0.177
	Sodium chloride	500,000	3.6	55	0.099	1.800	1.899
	Potassium chloride	120,000	3.6	55	0.023	0.432	0.455
					2.790	4.740	7.530

*Note that chlorine and caustic are produced simultaneously in electrolysis of brine. All of the electricity consumed in the process has been allocated to the primary product, caustic soda.

J. FERTILIZERS

J-1 Introduction

There are currently three major fertilizer producing operations, the Petroperu urea plant at Talara, the state-owned Cachimayo ammonium nitrate plant near Cuzco, and the Fertisa ammonium nitrate and ammonium sulfate plants in Callao. Other plants operate mixing and blending operations to produce various mixed fertilizers. Domestic production of fertilizers falls well below demand, requiring significant imports.

J-2 Existing and Planned Processing Facilities

The Cachimayo plant was commissioned in 1965 with a design capacity of 3000 MT per month of 33.5% nitrogen fertilizer. The plant uses large amounts of electricity to produce hydrogen from the electrolysis of water and nitrogen from an air separation plant. The nitrogen and hydrogen are converted to ammonia, while nitric acid is produced from air by an electrolytic (arc) process. Although the design capacity of the plant has rarely been reached, the plant is apparently now producing about 27,000 MT per year of ammonium nitrate.

The Fertisa plant at Callao has an installed capacity for 15,400 MT per year of 21% ammonium sulfate and 36,000 MT per year of 33.5% ammonium nitrate. Hydrogen for ammonia manufacture is obtained by reforming a residual fuel oil fraction.

The Talara urea plant was commissioned in April 1975 to produce 300 MT per day of ammonia from a natural gas feedstock, and to convert this to 510 MT per day of urea (46% nitrogen).

There are plans for a major phosphatic fertilizer complex to be built at Bayovar. The project includes plants to produce diammonium phosphate and triple superphosphate fertilizers. It is also planned to develop local brine evaporation ponds to produce potassium and sodium chlorides. According to the "Andean Report" of July 1977, it is hoped that the first stage of the Bayovar complex can be commissioned in 1982 to produce the following:

Phosphate rock	880,000 MT per year
Sulfuric acid	550,000 MT per year
Phosphoric acid	370,000 MT per year
Triple Superphosphate (46% P_2O_5)	370,000 MT per year
Diamm. Phosphate	150,000 MT per year

From the brine deposits, the second stage of the project will produce:

Potassium chloride (60% as K_2O)	100,000 MT per year
Sodium chloride	120,000 MT per year

Surface mining and conventional five-step processing (scrubbing, desliming, flotation, filtering, drying) will produce a fertilizer with 30.5% P_2O_5, suitable for immediate local use. About 8,000 MT is to be marketed locally and the balance used for making phosphoric acid or triple superphosphate.

J-3 Activity Data

The following data is derived from government statistics:

	Metric Tons		
	1975	1976	1977
Agricultural amm. nitrate	57,722	53,191	52,639
Compound fertilizers	17,759	16,036	22,572
Calcium superphosphate	7,237	10,250	7,769
Ammonium sulfate	8,785	7,807	7,357
Urea	47,492	100,364	117,862

J-4 Current Energy Consumption and Energy Efficiency of Existing Plants

Comprehensive data on energy consumption in the fertilizer sector was not available. However, some information on the Fertisa and Talara operations was obtained, and approximate estimates for other activities were based on typical industry practice. Energy use is summarized in Exhibit J-2.

The Incitemi report quotes the following energy consumption for Fertisa in 1976 (apparently in the form of No. 2 oil):

Electricity generation	127,000 barrels
Synthetic gas and other process uses	103,000
	230,000
Equivalent energy use	1.43×10^{15} joules

Based on discussions with Petroperu, energy use at Talara amounts to about 17 million SCFD of natural gas, of which 7 million SCFD represen feedstock and the balance is fuel for electricity generation and process use. Thus the total energy use (as natural gas) is about 36×10^9 joules/MT of urea.

With respect to energy requirements for mixing and blending fertilizers, data was taken from a report by Cornell University* and the total energy input calculated to be 460 x 10^6 joules per MT (of which about 15% is electricity).

J-5 Projected Energy Consumption

Estimates of energy consumption for 1985 and 2000 were made by pro-rating 1976 consumption where appropriate. Data for phosphate rock and associated fertilizer production was based on Cornell Unversity data. A summary of energy projections is given as Exhibit J-3. The growth in domestic fertilizer production from 1976 to 2000 represents a compound rate of about 8 % per year.

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* "Energy Requirements for New York State Agriculture" (Part 2, indirect inputs), Agricultural Extension Engineering Bulletin 400, Cornell University (1976).

EXHIBIT J-1

FERTILIZERS

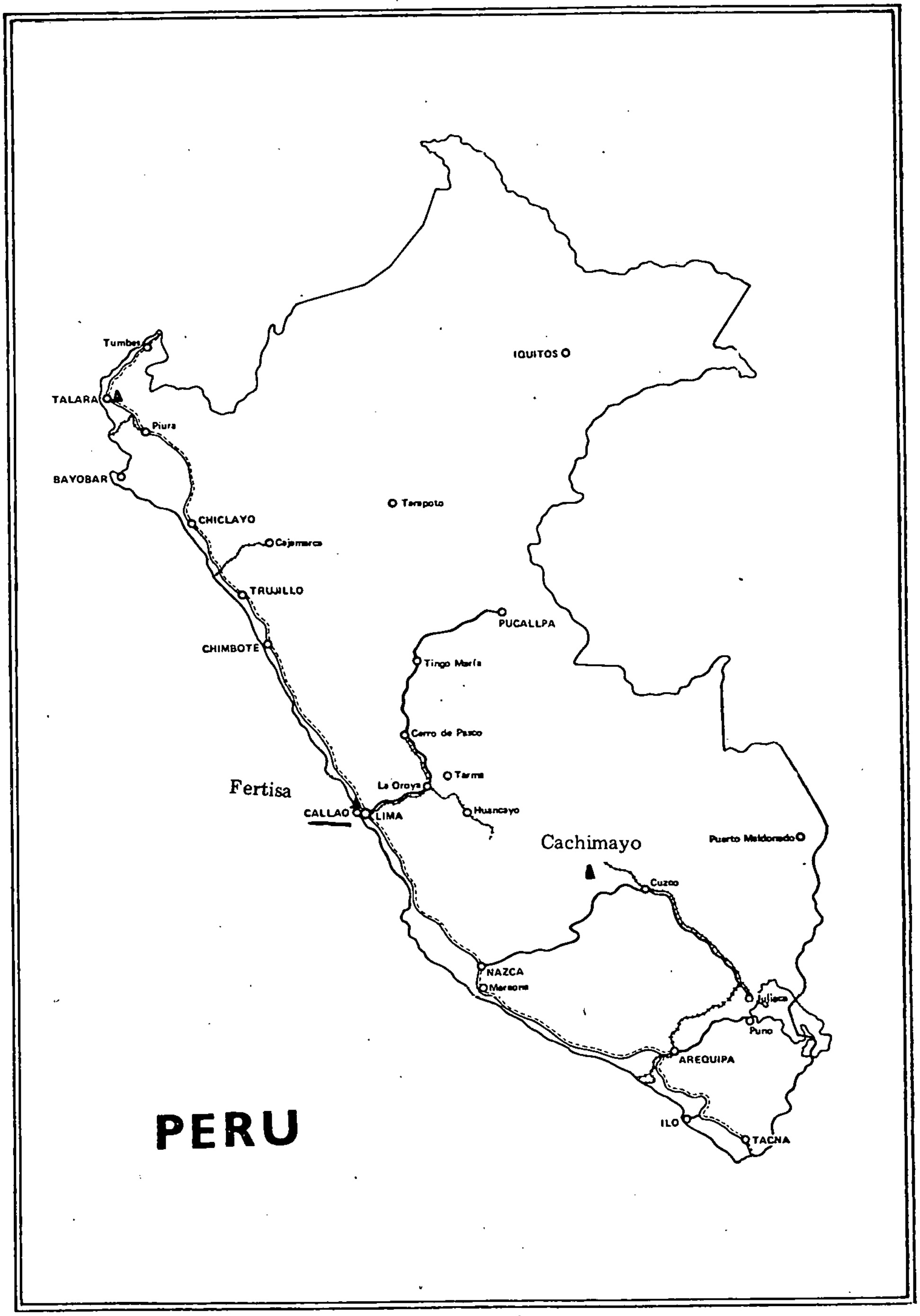

EXHIBIT J-2

ESTIMATED ENERGY CONSUMPTION FOR THE FERTILIZER SECTOR, 1976

Item	Approx. Production MT	Fuel Efficiency 10^6 Kcal/MT	Elec. Efficiency kWh/MT	Annual Energy Consumption 10^{15} joules		
				Fuel	Elec.	Total
Amm. Nitrate (Cachimayo)	27,000	2.05	6305	0.23	0.58	0.81 (2)
Amm. Nitrate (Fertisa)	26,000	-	-	1.43	(self gen.)	1.43
Amm. Sulfate (Fertisa)	7,800	-	-	-	-	- (1)
Urea (Talara)	100,400	-	-	4.37	(self gen.)	4.37
Miscellaneous Compounding and Mixing	40,000	-	-	0.02	-	0.02 (2)
TOTALS	201,200			6.05	0.58	6.63

(1) Included with ammonium nitrate figure.

(2) Based on rough estimate by Gordian.

EXHIBIT J-3

ESTIMATES OF PROJECTED ENERGY CONSUMPTION FOR THE FERTILIZER SECTOR, 1985/2000

Item	Approximate Production MT	Annual Energy Consumption 10^{15} Joules: Fuel	Electricity	Total
1985				
Amm. Nitrate(Cachimayo)	35,000	0.30	0.75	1.05
Amm. Nitrate(Fertisa)	36,000	1.97	--	1.97
Amm. Sulfate(Fertisa)	15,000	(included in above figure)		
Urea(Talara)	170,000	7.40	--	7.40
Misc. Compounding/Mixing	75,000	0.02	0.01	0.03
Phosphate rock(Bayovar)	300,000	0.54	0.05	0.59
Phosphoric acid(Bayovar)	125,000	1.89	0.15	2.04
TSP(Bayovar)	125,000	0.02	0.02	0.04
Diamm. phosphate(Bayovar)	50,000	0.88	0.03	0.91
	931,000	13.02	1.01	14.03

Item	Approximate Production MT	Fuel	Electricity	Total
2000				
Amm. Nitrate(Cachimayo)	35,000	0.30	0.75	1.05
Amm. Nitrate(Fertisa)	70,000	3.84	--	3.84
Amm. Sulfate(Fertisa)	30,000	--	--	--
Urea(Talara and others)	500,000	21.75	--	21.75
Misc. Compounding/Mixing	150,000	0.06	0.02	0.08
Phosphate rock(Bayovar)	880,000	1.57	0.16	1.73
Phosphoric acid(Bayovar)	370,000	5.60	0.44	6.04
TSP(Bayovar)	370,000	0.06	0.05	0.11
Diamm. phosphate(Bayovar)	150,000	2.64	0.10	2.74
	2,555,000	35.82	1.52	37.34

K. OTHER MANUFACTURING ACTVITIES

K-1 Introduction

The industrial sector of Peru is quite diverse, and there are many important industries other than those already discussed in this report. These include, for example:

Shipbuilding	Machine tools
Boilermaking	Glass products
Heavy engineering	Synthetic resins
Electrical machinery	Synthetic fibers
Automotive industry	Textiles
Pulp and paper	Brewing

In terms of energy, these industries are undoubtedly much smaller (individually) than the major industries studied in some detail, and therefore it was decided, for reasons of time, to exclude them from this study. However in the course of data gathering for the main industries, some miscellaneous information was received on other industries, and this is summarized for record purposes in this section.

K-2 Paper

A new plant using the "Cusi" process to convert bagasse to newsprint is to start operation at Santiago de Cao late this year. Initial capacity will be 110,000 MT per year: maximum electrical demand is expected to be 25 MW and annual electrical use will be 134,640 MWH (0.48×10^{15} joules). The plant is to be expanded to 220,000 MT per year in the early 1980's. It should be noted that this plant will initially take 400,000 MT per year of bagasse as a chargestock from the Casagrande sugar complex (which normally produces 750,000 MT per year). This will require replacing as a fuel at the sugar complex, and it appears this will have to be in the form of fuel oil (400,000 MT per year of bagasse is equivalent to about 4.4×10^{15} joules, or 720,000 bbls. oil equivalent).

K-3 Brewing

Long term, there are a number of expansion plans for this subsector. Capacity is likely to increase as follows (Andean Report, July 1977):

		Million Hectolitres		
		1976 Capacity	By 1985	By 2000
Backus & Johnston ("Cristal")	Lima/Rimac	2.25	2.25	Closed down
Backus & Johnston ("Cristal)	Lima/new	-	0.50	8.0
Comp. Nacional de Cerveza ("Pilsen")	Saenz Pena	0.65	0.65	0.65
Comp. Nacional De Cerveza ("Pilsen")	Modelo	0.65	1.30	3.15
Cerveceria del Centro	Huancayo	-	0.25	1.00
Soc. Cerveceria de Trujillo	Trujillo	-	0.45	0.45
Cerveceria San Juan	Pucallpa	0.30	0.30	0.30
Cerveceria del Sur Del Peru	Arequipa (2)	N/A	N/A	N/A
Cerveceria del Sur Del Peru ("Cuzqueña")	Cuzco	N/A	N/A	N/A
Cerveceria del Sur Del Peru ("Cuzqueña")	Puno	-	(?)	(?)
Cerveceria del Norte ("Garza Blanca")	1 plant	0.40	0.40	0.40
		4.25	6.10	13.95

No details of energy consumption in these breweries was obtained. However, on the basis of typical industry practice, rough estimates of energy use can be made:

	10^6 hectolitres	Energy Use 10^{15} joules
1976	4.25	0.99
1985	6.10	1.43
2000	13.95	3.26

L. AGRICULTURE AND RELATED ACTIVITIES

L-1 Background

In 1976, agricultural production registered a 3 percent increase, about the same as the population increase, and Peru continued to import significant quantities of agricultural products such as wheat, feed grains, dairy products and soybean oil. Of the total GNP in 1976, about 13 percent corresponds to the agricultural sector and 40 percent of the labor force is engaged in agricultural activities. With respect to balance of trade, agricultural imports totalled about $341 million, and exports totalled $308 million. While prices for coffee, cotton and wool were good, there was a 71 percent drop in the export value of sugar. The unfavorable balance of $33 million in 1976 compares with a positive balance of $12 million in 1975.

Peru's agricultural policy revolves around the "Agrarian Reform" program. The purpose of the program which started (for practical purposes) with the passing of the 1969 agrarian law, is to redistribute land from the largest landowners to the people. Large estates like sugar plantations are now formed into worker's cooperatives. The reform program has affected about one-third of all land in agricultural use, which totals about 30 million hectares. Of this 30 million, a little over 3 million is arable land (mostly on the coast) with 1.2 to 1.5 million irrigated and 1.8 million dry farmed. The remaining 27 million hectares is pasture, much of it poor quality. By December 1976, estimates of the total land expropriated were as follows:*

	Million Hectares
54% of coastal land	1.5
One-third of pasture	9.0
	10.5

In passing, it should be noted that most of the land in the coastal area of the country needs irrigation. However, over-irrigation in some places, and a lack of attention to drainage and land contouring, have led to problems of salinity and waterlogging in about one-fifth of the irrigated area. Technical and financial assistance to alleviate this problem is being provided by the World Bank.

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* Andean Report, March 1977.

L-2 Some Statistics

Exhibit L-1 summarizes agricultural sector activity for the period 1961 through 1976. It is important to note from this exhibit that the index of per capita food production has in fact dropped to 81 relative to 1961-1965 as the base period. There is therefore strong emphasis by the government to improve production in the agricultural sector, with the ultimate goal of becoming self-sufficient.

Exhibit L-2 indicates the areas under cultivation and the yields per hectare for major crops.

L-3 Irrigation

Major irrigation projects, and estimates of the area of land to be brought into cultivation, are as follows:

		Hectares of New Land	Hectares of Improved Land	Approx. Date of Completion
1.	Chira-Piura	150,000	35,000	1978
2.	Majes I	23,000	-	1980
	Majes II	34,000	-	1982
3.	Tinajones I	6,000	59,000	1979
	Tinajones II	90,000	-	1985
4.	Jequetepeque-Zana I	16,400	30,000	1982
	Jequetepeque-Zana II	-	10,000	1985
5.	Olmos I	80,000	-	1983
	Olmos II	48,000	-	1986
6.	Pungayo-Tumbes	36,000	10,000	1983
7.	Patavilca	6,700		(?)
8.	Chao-Viru-Moche-Chicama	70,000	80,000	(?)
9.	Coastal valley drainage (Lima-Arequipa)	-	18,000	(?)
		802,100	242,000	

A total of about 812,000 hectares of new or improved land is expected to result from these projects by about 1985, an increase of 27% over the current arable land area of 3 million hectares.

L-4 Current and Projected Crop Levels and Energy Needs

According to sources in the Ministerio de Agricultura y Alimentacion, the overall sectorial growth is expected to be as follows:

1978-82 About 3.0% per year (same as population increase)

1982-85 About 3.1%

1986 and beyond Between 3.5 and 4.0%

While these figures may seem somewhat high in relation to past performance, they will be used in projections of the growth of energy consumption in the sector.

In order to estimate energy needs for the agricultural sector, the following methodology was used. Exhibit L-3 lists crop yields, hectares planted, required fertilizer inputs and machinery-hours for major crops, as given in the latest "Plan Operativo" for the year 1977. Exhibit L-4 shows that, based on fertilizer inputs and machinery-hours (at 2 gallons petroleum-based fuel per hour), a total energy input of about 6.4×10^{15} joules is required for the initial crop list (excluding sugar, cotton and tobacco).

Clearly, the figure of 6.4×10^{15} joules does not include any irrigation energy input. In order to estimate the probable magnitude of this element, in the absence of specific data on diesel oil consumption* for pumps, Exhibit L-5 was prepared. This is a listing of US data on energy inputs for various crops, from which it may be deduced that a reasonable figure for irrigation energy using groundwater pumping would be 20×10^{9} joules per hectare irrigated (based on the fact that corn, rice, sugar and cotton represent the largest areas under irrigation in Peru). This figure is used in Exhibit L-4.

With respect to energy inputs for sugar cane, cotton and tobacco, it was decided to use US data (subtracting the irrigation input, already included in the calculation). It is, of course, recognized that this provides very approximate figures, as there are obvious differences in climate, farming methods, yields per hectare, fertilizer application rates, crop strains, etc.

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* Most pumping by diesel-driven pumps; apparently there is little electric pumping, although Electroperu has studied the possibility of converting from diesel in the Medio Sur area.

Thus Exhibit L-4 shows a total energy input for the listed crops of about 12 x 10^{15} joules per year (taken as the base situation for 1976). For energy balance purposes, a figure of 6.2 x 10^{15} joules should be used, because the fertilizer energy input is already included in the industrial sector energy consumption for fertilizer manufacture. Where fertilizers are imported, the "invested" energy should not be included in the domestic Peruvian energy balance.

Projections of energy needs are shown in Exhibit L-6; the basis for the projections are indicated. Energy needs for the listed crops rise to 8.0 and 12.3 x 10^{15} joules for 1985 and 2000 respectively.

L-5 Livestock and Poultry

Insufficient data was received for any meaningful estimates to be made of energy consumption in the raising of livestock and poultry. It is known that there are proposals by Intintec to start experiments with solar heating for raising chickens, which might be particularly important around Puno where the high altitude leads to rather cold conditions for optimum reproduction and egg-laying.

L-6 Fishing

As there was no time available to investigate the fishing industry or other activities related to food production, no energy projections have been made. However, the total electricity use for the fishing sector for 1976 is reported by the Ministerio de Energia y Mines as 67.7 x 10^6 kWh, less than 1% of the total electricity consumption for the nation. By contrast, the agricultural sector is reported to have consumed 292.9 x 10^6 kWh (3.7% of the total): this is equivalent to 1.05 x 10^{15} joules, about 17 percent of the total calculated energy consumption for the agricultural sector crops listed in the previous section.

From discussions with Petroperu, it appears that the fishing sector consumed the following petroleum products in 1977:

	10^3 Barrels	10^{15} Joules
No. 5 and 6 residual fuel	800	5.30
No. 1 and 2 diesel	600	3.69
	1400	8.99

Projections by Petroperu for 1985 show an increase in consumption to the following:

	10^3 Barrels	10^{15} Joules
No. 5 and 6 residual fuel	1400	9.28
No. 1 and 2 diesel	700	4.30
	2100	13.58

No other data was collected.

L-7 Food Processing

Again, there was insufficient time to investigate energy consumption in food processing. In fact, this subsector is generally included in the national industrial sector statistics. The 1977 Incitemi report on coal use in Peru indicated that the major sugar cooperatives use a total of about 1,114,000 barrels of residual fuel oil for electricity generation and other process uses, plus about 200,000 barrels of diesel oil for sugar cane transportation. In addition, there is an extensive use of bagasse as a fuel, except of course where bagasse is already being used as a chargestock for paper plants. With respect to the cooperatives, the Icitemi report indicates the following use of bagasse:

	Percent used for electricity generation
Paramonga	0 (used for paper)
San Jacinto	80
Cartavio	50
Casagrande	50
Laredo	50
Tumán	~100
Pucalá	~100
Cayaltí	~100
Pomalca	~100

With the increasing use of bagasse for papermaking, it is anticipated that all bagasse will have been removed from fuel use by 1985, necessitating replacement with petroleum based fuels (and possibly by coal in the longer term).

L-8 Crop Residues

The potential for recovery of useful energy from crop residues has been little explored in Peru. With the exception of the use of sugar cane bagasse, other residues are apparently little used, except perhaps in the Sierra where all kinds of animal and vegetable wastes and wood are believed to be used by the villagers. An analysis of the potential for energy recovery from biomass is outside the scope of this study, but the following figures for major crops indicate the order of magnitude of energy potentials:*

	10^3 MT Production	10^{15} joules/year
Rice	532	6.0
Corn	394	32.0
Sorghum	46	1.3
Wheat	877	45.4
Beans	51	4.3
Potatoes	69	0.3
Sugar cane	-	65.6

* Data source: SRI, "Effective Utilization of Solar Energy to Produce Clean Fuel" (1974), quoted in the USGS "Preliminary Report on the Energy Resources of Peru", 1978.

EXHIBIT L-1
PRODUCTION BY COMMODITY, VALUE AND INDICES OF TOTAL AGRICULTURAL AND FOOD PRODUCTION, AVERAGE 1961-65, ANNUAL 1967-76

Commodity	Average 1961-65	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
Wheat	150	152	119	137	125	122	140	149	150	143	148
Rice, Paddy	324	461	286	444	587	591	552	451	426	473	530
Corn	490	591	533	585	615	616	589	616	600	625	670
Barley	185	172	146	164	170	159	160	165	168	168	165
Millet	25	17	6	9	9	8	8	8	8	8	10
Sorghum	2	4	5	12	15	18	20	22	18	30	45
Beans, Dry	39	65	40	50	53	48	47	37	35	36	36
Potatoes	1,487	1,712	1,592	1,856	1,929	1,968	1,750	1,713	1,722	1,700	1,750
Cassava	436	507	399	450	498	482	490	460	669	670	675
Sweet Potatoes	148	150	145	156	178	168	170	155	146	150	155
Sugarcane	7,373	7,373	7,226	6,214	7,530	8,291	8,582	8,746	9,176	8,928	8,940
Tobacco	3	5	4	3	3	2	3	4	5	5	5
Cotton	140	91	101	89	91	77	73	84	83	71	57
Cottonseed	233	153	180	151	159	122	115	149	160	132	102
Coffee	48	53	52	56	59	62	62	60	54	54	57
Cattle Imports(1)	76	85	62	81	113	101	87	30	10	10	10
Beef and Veal	91	93	90	88	85	111	96	85	84	86	88
Mutton and Lamb	38	37	37	33	33	33	31	34	35	37	39
Pork	43	41	40	47	46	54	42	45	46	47	48
Wool, Greasy Basis	11	10	10	10	10	11	8	9	9	9	9
Aggregates of Production	---MILLION DOLLARS AT CONSTANT PRICES---										
- Crops	345.7	350.3	321.5	345.5	374.3	369.0	352.3	351.5	353.1	347.3	350.3
- Livestock	61.9	60.0	61.1	59.4	53.9	69.7	58.5	63.2	65.9	67.5	69.4
- Livestock Feed Deduction	-8.6	-8.4	-8.5	-8.3	-7.5	-9.7	-8.1	-8.8	-9.2	-9.4	-9.7
- Total Agriculture	399.0	401.9	374.1	396.6	420.7	429.0	402.7	405.9	409.8	405.4	410.0
- Total Food	285.3	313.5	280.8	303.3	329.6	344.0	321.4	318.6	326.1	328.6	339.5
Indices of Production	(1961-65 = 100)										
- Crops	100	101	93	100	108	107	102	102	102	100	101
- Total Agriculture	100	101	94	99	105	108	101	102	103	102	103
- Total Food	100	110	98	108	116	121	113	112	114	115	119
- Per Capita Agriculture	100	90	81	84	86	85	78	76	74	72	70
- Per Capita Food	100	98	85	91	94	96	87	84	83	81	81
Index of Population 1961-65 Population = 10,902,000	100.0	111.8	115.2	118.6	122.3	126.0	129.8	133.7	137.9	142.1	146.3

(1) In 1,000 head.
Source: U.N. data

EXHIBIT L-2

AREA AND PRODUCTION OF MAJOR AGRICULTURAL COMMODITIES

	1975			1976		
	Area 10^3 Hectares	Production 10^3 MT	Yield MT/Hectares	Area 10^3 Hectares	Production 10^3 MT	Yield MT/Hectares
Wheat	137	143	1.04	140	148	1.06
Rice	118	473	4.01	122	530	4.34
Corn	370	625	1.69	400	670	1.68
Barley	187	168	0.90	185	165	0.89
Dry beans	50	36	0.72	50	36	0.72
Potatoes	265	1700	6.42	270	1750	6.48
Cassava	38	670	17.63	39	675	17.31
Sweet potatoes	14	150	10.71	14	155	11.07
Sugarcane (1)	55	8928	162.33	57	8940	156.84
Raw Sugar (2)	91	990	10.88	92	950	10.33
Tobacco	5	5	1.00	5	5	1.00
Cotton	146	73	0.50	104	57	0.55
Coffee	128	54	0.42	128	57	0.45

(1) Area harvested
(2) Area planted

EXHIBIT L-3

AGRICULTURAL SECTOR PRODUCTION ESTIMATES

AND ENERGY NEEDS

	Area Hectares	Production MT	Fertilizer use MT N	P	K	Thousand Machine Hours
Rice	108,922	532,103	24,173	451	39	624.3
Corn	141,572	394,328	18,381	9,747	2,193	1298.6
Sorghum	20,948	45,884	3,125	906	--	199.0
Potato	73,830	69,014	10,346	9,520	7,177	537.0
Wheat	29,804	876,919	2,286	2,197	118	148.0
Beans	19,657	51,359	790	982	96	215.0
Soya	3,050	22,781	--	--	--	23.0
Peanuts	480	960	14	28	20	--
Quinua	4,558	4,558	365	183	--	27.8
Pallar	2,625	2,625	105	157	--	--
Onion	2,407	58,585	330	185	106	23.3
Tomato	372	12,324	103	43	32	4.9
Choclo	424	4,560	42	38	36	3.0
Banana	12,504	153,072	1,093	224	446	14.3
Orange	3,039	39,546	525	250	472	2.3
Apple	85	761	18	8	2	0.7
Lemon	3,175	25,836	423	99	230	6.3
Mango	4,053	36,075	478	159	302	13.4
Avocado	619	4,077	91	35	69	1.8
Grapes	2,086	16,740	234	228	172	40.2
Other fruits	1,471	2,909	179	126	109	1.9
Totals	435,681		63,101	25,566	11,619	3185.0
Sugar Cane	57,000					
Cotton	104,000					
Tobacco	4,228					
Total	600,909					

	10^{15} joules
Energy input for fertilizers =	5.515 (1)(2)
Energy input for machinery =	0.860 (1)

(1) Fertilizer energy input taken as 80×10^9 J/MT for nitrogen, 14×10^9 J/MT for phosphate and 9×10^9 J/MT for potash. Machinery consumption averages 2 gallons per hour, say 270×10^6 J per machine-hour. (Sources of data: machinery, Min. Agricultura y Alimentacion; fertilizers, "Energy and Food Production" by Gerald Leach, IPC Science and Technology Press).

(2) Note, however, that energy for domestic fertilizer manufacture is already included in the fertilizer subsection of this study. Also, energy included in imported fertilizers is not to be counted as part of the domestic Peruvian energy balance.

EXHIBIT L-4

ENERGY CONSUMPTION ESTIMATES FOR AGRICULTURE, 1976

	10^{15} J/year
Listed Crops	
fertilizer energy input	5.52
machinery input	0.86
[1] irrigation ($0.25 \times 20 \times 10^9 \times 0.6 \times 10^6$)	3.00
Miscellaneous inputs[2]	
sugar cane ($19.0 \times 10^9 \times 57{,}000$)	1.08
cotton ($7.9 \times 10^9 \times 104{,}000$)	0.82
tobacco ($105.0 \times 10^9 \times 4228$)	0.44
SUBTOTAL	11.72
Less fertilizer energy input	5.52
TOTAL for energy balance purposes	6.20

Notes

1. Assumes 100% irrigation of the major crop areas (602,000 hectares). Most of this is in the coastal region and it is assumed that the pumping input is 20×10^9 J/hectare, but that only about 25% of irrigation requires this pumping. The balance is by gravity flow from dams and rivers. The remaining 600,000 hectares which are irrigated for the production of other crops in Peru (and for subsistence farming and livestock rearing) are assumed to receive essentially all water by gravity flow.

2. See Exhibit L-5.

EXHIBIT L-5

U.S. DEPARTMENT OF AGRICULTURE DATA ON ENERGY CONSUMPTION (1974 DATA BASE)

Crop	10^3 Btu per acre for specified inputs[1] Fertilizer Input	Pesticide Input	Irrigation Input	10^3 Btu per Acre Total Input	10^9 J/hectare[2] irrigation per hectare irrigated
Rice	3788	779	5829	17648	16.8
Corn	3702	233	702	7658	20.9
Sorghum-grain	2385	268	2611	7286	27.0
Potato	11175	1149	2050	20694	17.5
Wheat	851	24	59	2285	13.0
Beans(dried)	1820	245	285	6703	8.7
Soya beans	300	140	35	2368	13.1
Peanuts	1001	1481	1021	8136	17.4
Quinua	3000E	300E	1600E	20000E	15.0
Pallar	3000E	300E	1600E	20000E	15.0
Onions	5000E	636E	1600E	14800E	14.5
Tomato	5000E	636E	1600E	14000E	15.0E
Choclo-Maize	3000E	300E	1600E	8000E	20.0E
Bananas	6000E	3500E	2000E	40000E	10.0E
Oranges	6000E	3622	2128	45965	7.9
Apples	5434	4519	2267	29533	25.7
Lemons	6414	920	5150	43437	28.0
Mangos	5000E	2000E	2000E	30000E	25.0E
Avocado	5000E	2000E	2000E	30000E	25.0E
Grapes	1964	2303	1559	12400	10.5
Other fruits	4607	1263	884	16180	13.3
Sugar cane	4365	547	3069	15320	20.7
Cotton	2525	3017	2275	10833	19.3
Tobacco	4000E	2000E	1150E	47256	6.3

(1) Machinery inputs by difference from total shown.
(2) Conversion factor = Btu/acre x 2607 = Joules/hectare
(3) Energy input for these crops is estimated as follows (excluding fertilizer, pesticides and irrigation):

	10^3 Btu/acre	10^9 Joules/hectare
Sugar cane	7300	19.0
Cotton	3000	7.9
Tobacco	40000	105.0

E = rough estimate.

EXHIBIT L-6

PROJECTED AGRICULTURAL ENERGY CONSUMPTIONS, 1985/2000

	1976 Base 10^{15} joules	Changes	1985 10^{15} joules	Changes	2000 10^{15} joules
Machinery input	0.86	Escalate at 3.0% to 1982, 3.1% to 1985	1.13	Escalate at 4% after 1985	2.03
Irrigation	3.00	About 27% more land under irrigation by 1985	3.81	Assume 25% more land under irrigation by 2000	4.76
Miscellaneous Crops	2.34	(see machinery)	3.06	Escalate at 4% after 1985	5.51
TOTALS	6.20		8.00		12.30

M. SUMMARY OF ENERGY CONSUMPTION ESTIMATES

Exhibit M-1 presents a summary of the energy consumption figures derived in this study. As an indication of the "coverage" provided by the industry subsectors which were investigated in some detail, the total industrial, mining and agricultural sector energy use for 1976 was about 146 x 10^{15} joules.* The "calculated" energy was as follows:

	10^{15} joules
Mining and non-ferrous metals	28.9
Industry	34.6
Agriculture	6.2
	69.7

This represents approximately 50% of the total consumption by these sectors.

It is perhaps appropriate at this point to note that the projections of energy consumption for 1985 and 2000 are based, for the most part, on the construction of new facilities and their operation at or near full capacity. In some cases, a growth rate for the subsector was specified and used to estimate changes in energy use. In fact, no direct economic input was used for the projections. It is clear that the general state of the domestic economy, coupled with important external factors such as the world price for copper, iron ore, sugar, etc., will determine the level of activity for any subsector at any time. The energy projections given in this report must therefore remain subject to modification according to macro-economic projections through 2000.

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* Brookhaven National Laboratory "A Preliminary Assessment of the Energy Supply-Demand Situation in Peru" (draft, January 1978).

EXHIBIT M-1

SUMMARY OF ENERGY CONSUMPTION ESTIMATES

	1976				1985				2000		
	Elec.	Petr.	Coal/ Coke	Total 10^{15} J	Elec.	Petr.	Coal Coke	Total 10^{15} J	Elec.	Petr.	Coal/ Coke
Mining & Non-Ferrous	7.05	20.24	1.58	28.87	18.43	48.39	1.58	68.40	34.27	86.08	3.16
Industry											
Iron & Steel	0.72	1.81	6.04	8.57	1.67	4.23	16.30	22.20	6.57	16.93	57.03
Cement	0.85	9.16	0	10.01	1.69	15.35	0	17.04	3.38	28.99	0
Oil Refining	0.52	6.07	0	6.59	0.86	10.45	0	11.31	1.37	16.57	0
Petrochemicals	0.03	0.22	0	0.25	0.03	0.32	0	0.35	1.34	6.20	0
Chemicals	1.01	1.53	0	2.54	1.45	4.04	0	5.49	2.79	4.74	0
Fertilizers	0.58	6.05	0	6.63	1.01	13.02	0	14.03	1.52	35.82	0
Total	3.71	24.84	6.04	34.59	6.71	47.41	16.30	70.42	16.97	109.25	57.03
Agriculture				6.20				8.00			

N. OPTIONS FOR ENERGY SAVINGS

A preliminary review of the data collected in the course of this study, and of the discussions held with a variety of government officials and operating personnel in the industrial and mining sectors, suggests the following topics as worthy of consideration in the development of options for energy savings:

(1) Conduct an energy efficiency audit of major energy-consuming subsectors, and develop programs and goals for energy conservation.

(2) Investigate the application of computer-modeling techniques to petroleum refinery operations, primarily for short-term plant optimization.

(3) Promote the use of coal in the industrial, mining and agricultural sectors.

(4) Develop and initiate training programs to improve management techniques in energy analysis and planning (emphasizing the systems approach) and to improve project management in the realization of energy-related projects.

(5) Investigate the potential for using waste industrial products (slags from iron and copper activities) and naturally-occuring volcanic ashes (pozzolans) in the manufacture of blended cements. Develop an implementation plan, including any necessary R and D to establish quality-control parameters.

(6) Investigate the use of slags from metallurgical operations as lightweight aggregates for the construction industry.

(7) Investigate the use of slags from metallurgical operations as sources of insulating material (glass fibers).

(8) Study the potential for use of agricultural waste materials as energy sources, and develop an implementation program.

(9) Investigate the potential for substituting (mineral) coke by charcoal derived from natural products in metallurgical operations.

(10) Develop a plan for the use of coal as a feedstock for fertilizer manufacture.

(11) Investigate the extent of existing cogeneration systems and the potential for new systems (retrofit or new projects).

(12) Study the substitution of oil by hydroelectric power in the industrial and mining sectors (implementation being dependent on hydroelectric availability).

(13) Study the potential for utilizing geothermal energy at mining sites in the Arequipa area.

(14) Develop an integrated energy-industry-agriculture plan for one small region of the country, and initiate a pilot program for its evaluation at a practical level.

Further notes on items 1 through 5 are included as attachments to this section, as these measures are believed to have particular merit with respect to the short to medium term energy situation.

It is appropriate at this point to note that most indications gained during the two weeks of this study suggest that the current energy efficiency of the Peruvian industrial sector is generally at a good level with respect to standard industry practices. For example, the petroleum refinery at La Pampilla was visited and it appears that this plant is kept in excellent mechanical condition and is operated conscientiously and efficiently. Visits to other plants were made and the same general impression was obtained (see Section P). In all plants, however, there will exist some areas of improvement, and it is therefore considered important that an energy efficiency audit be conducted to monitor efficiency in all major energy-consuming sites, and a program for promoting energy conservation be developed and initiated. Often such energy conservation efforts can provide a significant contribution to energy demand reduction for a minimum of capital investment and in the shortest possible time.

Finally, some of the proposed options deal with "fuel switching", primarily the promotion of coal use by industry. There are undoubtedly many uses for coal in industry (e.g. in cement plants) provided coal can be provided within appropriate economic and environmental constraints. One other aspect of "fuel switching" is the increased use of hydro-electricity (item 12); some thoughts on a maximum electrification strategy are given in Exhibit N-3.

STRATEGY: INDUSTRIAL ENERGY EFFICIENCY- IMPROVEMENT

Energy-Savings

Prior to carrying out further investigation, it is not possible to project potential energy savings with any certainty. However, useful savings appear highly likely because much of the fuel used in industry is petroleum-based, and much of the electricity is generated from petroleum-based fuels. A saving of 10 percent of petroleum use by the industry and mining/non-ferrous sectors by 2000 is judged to be a conservatively low estimate. In comparison, existing energy conservation targets in the US are for an overall energy efficiency improvement of about 14 percent by the top 10 energy consuming industries over the period 1972-1980. Thus potential savings in Peru should approach 40×10^{15} joules per year by 2000. A breakdown of the anticipated savings follows as Exhibit N-1.

Major industrial or resource requirements

Installation of various types of industrial equipment (heat exchangers, instrumentation, pumps, motors, etc) will be required as measures for greater processing efficiency are adopted. It is also likely that material needs (e.g. insulation) will be significant.

Manpower requirements

Plant modifications will be performed by the existing construction industry (mechanical, electrical, civil). Some additional manpower may be required, especially if a major shift to coal use also takes place over the next decade.

General training requirements

Training in various aspects of energy auditing, conservation and cost benefit analysis is suggested for technical staff, and training at plant operator level (including operating supervision) is also suggested, to stress practical aspects of energy efficiency improvement. Training programs might be developed at US locations for both operating and technical personnel.

Organizational infrastructure

Improved energy efficiency depends heavily on good management of manufacturing facilities. While the existing organizational structure of companies may prove adequate, it is recommended that companies develop a special "department" responsible for energy consumption monitoring and for energy reduction planning. This department must have proper authority to perform its duties, and this implies the full committment of company management to energy conservation.

If a "targets" system were to be developed, appropriate staff would be required within the Ministerio de Energia y Minas.

Environmental considerations

Improved energy efficiency normally leads to a reduction in the environmental impact of manufacturing facilities (by reducing fuel use, plant emissions will be reduced).

Other social and economic aspects

More efficient operations must improve the economy of individual manufacturing activities. In addition, reduced use of domestic petroleum resources will be beneficial: 1) a scarce resource can be made available for premium uses (e.g. chemical feedstock), 2) the availability of Peru's limited oil reserves can be extended over a longer period of time, 3) if deemed economically and politically acceptable, petroleum can be made available for export in order to earn hard currency and thereby alleviate balance of payments problems. A side benefit of improvements in energy efficiency will be the stimulation of that sector of the economy which supplies the equipment and materials for implementing energy conservation measures.

Cost Estimates

Investment needs by industry cannot be estimated without further detailed investigation. It should be possible to achieve significant efficiency improvement with little or no investment (adopting so-called "housekeeping" types of measures). The cost of developing energy efficiency programs, including appropriate monitoring systems and personnel training, requires evaluation but is likely to amount to at least $500,000 for a initial program of one year.

ITEM 1

Energy Option:

—End Use Energy Efficiency Improvement in the Industrial Sector.

Project Title:

Improved energy efficiency in manufacturing industry.

Objective:

To reduce current energy consumption per unit output in the industrial sector through improved energy management and adoption of energy conservation measures in manufacturing plants.

Scope:

Useful savings in energy consumption are obtainable through a systematic program to implement energy conservation practices and technologies throughout the industrial sector. Although a detailed study of conservation potential has yet to be made, an estimate of probable energy savings suggests that oil and gas resource savings equivalent to 36.5×10^{15} joules/year and coal resource savings of 0.6×10^{15} joules/year are readily attainable in 2000 (based on traditional fuel use patterns); approximately half of these savings could be achieved by 1985. A summary of assumptions used to derive these numbers is attached as Exhibit A.

The scope of a program to promote industrial sector energy efficiency could be quite broad, and therefore it is recommended that a phased approach be adopted, with the total effort spread over about 4 years. Thus a pilot program for one or two major ergy-consuming industries could be developed in the first year, and expanded to other industries as experience is gained. The overall effort could therefore be divided as follows:

1st year

(a) Establish data base for determination of current energy efficiencies in key industries
(b) Select two industries for pilot program
(c) Develop energy efficiency improvement targets for the two industries (five to ten year targets)
(d) Set up monitoring procedures with the participating representatives
(e) Develop appropriate training programs at plant operator, supervisor and technical management levels (governing energy conservation techniques, technological changes, cost benefit analyses, etc.)

2nd year

(a) Report on programs and data with the first two industries
(b) Extend program to, say, three additional industries. Develop energy efficiency improvement targets, and initiate monitoring procedures.
(c) Extend training programs to cover the "new" industries
(d) Develop training programs for key management and superisory personnel at selected US locations, to provide broader practical experience in energy-conservation programs.
(e) Continue monitoring energy efficiency in all selected industries.

3rd year

(a) Report on progress in first five industries
(b) Extend program to five further industries (maximum of ten being included in the total effort); develop energy efficiency improvement targets and initiate monitoring procedures
(c) Extend training programs to cover the "new" industries
(d) Continue training programs at US locations

4th year

(a) Prepare final report on program development and on all training programs
(b) Report on progress to date in meeting energy efficiency improvement targets
(c) Develop recommendations on monitoring procedures and training appropriate for a continuing effort.

Donor Activities:

These could include provision of personnel experienced in assembly of energy use data and its analysis, to assist in the development, initiation and conduct of the total program. For the four-year effort outlined above, a team of four engineers represents an appropriate level of effort.

Peruvian Activities:

Participation in the project would start at the level of about 4 engineers, increasing to around 10 as the program becomes fully operational. Major responsibility for the project would reside with the Ministerio de Energia y Minas operating in conjunction with the Ministerio de Industria (covering Siderperu, Induperu, and the cement, chemicals, fertilizers and paper sub-sectors), the Ministerio de Agricultura (e.g., sugar cooperatives) and the Ministerio de Pesqueria (Pescaperu), as appropriate to the industries chosen for study.

Resource Requirements:

(10^3 \$)	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Premium Cost	30	60	80	70	--	240
Donor Cost	175	225	250	200	--	850
Total	205	285	330	270	--	1090

Other requirements: (equipment, etc.)

Computer time may be required if the data-gathering and monitoring activities are performed using a computer-based system.

EXHIBIT N-1

ENERGY EFFICIENCY IMPROVEMENT OPTION: BREAKDOWN OF POTENTIAL SAVINGS BY ENERGY TYPE

The potential impact by 2000 of a major energy efficiency improvement program has been estimated using the basic data on industrial energy consumption which was developed during the Peru energy study. The energy saving potential for each of the subsectors was derived as follows:

1. For existing plants and those brought on line by 1985, guidance was obtained from the U.S. energy efficiency improvement "targets" program. The following assumptions were adopted for each subsector, from which energy savings by the year 2000 were estimated for "existing plants":

   Oil Refining

   Savings of about 5 percent of energy use were judged possible through "housekeeping" and minimum capital investment programs by 1985, with a further 5 percent possible through investment in energy-efficient equipment, process changes, etc., by 1985. An additional 5 percent was judged achievable by 2000, resulting in a total saving by 2000 of 1.5×10^{15} joules/year (some of this being natural gas, which is used as a fuel at Talara).

   Mining and Non-ferrous Metals

   The U.S. target for the non-ferrous metals processing industry (within SIC 33) is about 11 percent, and this refers to the seven year period between base year 1972 and January 1, 1980. An energy efficiency improvement of 1.5 times this figure was judged reasonable for the period 1978 to 2000 for plants commissioned prior to 1985 (that is, 16.5 percent savings).

   Iron and Steel

   The U.S. target is about 13.5 percent; a figure of 1.5 times this value was judged reasonable for the savings corresponding to electricity and petroleum fuels usage. With respect to coke use, the Peruvian industry is already quite efficient, and therefore a lower figure (5 percent) was judged appropriate.

Cement

The U.S. target is about 18 percent, but much of this is expected to be achieved through the conversion of wet to dry process plants. Since most of the Peruvian production is already based on efficient suspension-preheater dry process kilns, a figure of 10 percent was adopted.

Petrochemicals

This represents a small proportion of the present Peruvian industrial sector; plants are judged to be reasonably efficient already. A figure of 10 percent was adopted.

Chemicals

The U.S. target for the alkali and chlorine industry is about 9 percent, while that for industrial organic chemicals is 4 percent. A figure of 10 percent was adopted for the Peruvian industry.

Fertilizer

The U.S. target is 15 percent, and it was recognized that the Peruvian industry is already quite efficient (based on observations made during the plant visit to Fertisa at Callao). However, there appear to be some opportunities for installing cogeneration facilities at Fertisa, and for recovering waste heat from gas turbine exhaust (associated with electricity generation) at Talara. A figure of 15 percent, the same as the U.S. target, was therefore adopted.

2. For plants brought on line after 1985, which will presumably be designed to include best modern practice at the time of construction, it was assumed that savings would total no more than 7.5 percent of energy consumption by 2000. These savings would be obtained by the retrofit of technological developments and the incorporation of improved types of equipment in these "best practice" plants, as it is assumed that improvements will continue to be made in all sectors of industry over the period 1985 to 2000.

Note that a reduced level of savings was adopted for coke used in the iron and steel subsector: a figure of 2.5 percent was taken.

Using these basic assumptions, potential savings were estimated for the specified industries with the following results:

	Estimated Annual Savings Potential by 2000, (10^{15} joules)				
	Electricity	Oil	Gas	Coal/Coke	Total
Industry	1.8	7.5	1.1	0.5	10.9
Mining and Non-ferrous	4.3	7.6	--	0.1	12.0
	6.1	15.1	1.1	0.6	22.9
As % of total demand for specified energy type	11.7	10.1		3.7	9.1

In fact, the electricity savings are expected to result in a reduced demand for petroleum-based fuels, as it is assumed that marginal savings in electricity demand would allow reduction of load on gas turbine and diesel generators, while hydroelectric plants would continue at maximum output (base load plants). For an efficiency of generation, transmission and distribution of say 30 percent, the electricity savings therefore amount to a potential saving of 20.3 x 10^{15} joules of oil resource.

By 2000, the "increased energy efficiency" option for the mining and industrial sectors should therefore have at least the following impact on energy resources:

	Savings, 10^{15} joules/year
Oil	35.4
Gas	1.1
Coal	0.6
	37.1

The benefits of optimization will include improved product yield patterns less degradation of premium products such as gasoline to lower value products such as refinery gas), and this will have a corresponding effect on energy consumption. However, the benefits of computerized optimization can also include increased productivity of technical personnel, with little or no direct energy benefits. It is anticipated that the energy savings directly attributable to this project will amount to about 2.5% of total refinery energy use, assuming that reasonable efforts to optimize operations have already been taken through conventional means. This is equivalent to about 0.3×10^{15} joules per year by 1985, and 0.5×10^{15} joules by 2000.

Donor Activities:

This could include provision of, say, those technical personnel with modeling and refinery operations experience, who would work in conjunction with Petroperu staff. Training at appropriate refinery locations could also be provided.

Peruvian Activities: For practical purposes, participation in this project would be limited to Petroperu. A team of about six Petroperu personnel would be involved, playing a major role in data assembly and contributing their understanding and knowledge of specific refinery operations. Petroperu could also contribute to the use of computer facilities.

Resource Requirements:

Peruvian Cost	Year 1	Year 2	Total
Peruvian Cost (10^3 $)	30	45	75
Donor Cost	125	175	300
Total	155	220	375

Other requirements· (equipment,etc.)

Computer time (say 500 hours per year)

ITEM 2

Energy Option:

End Use Energy Efficiency Improvement in the Industrial Sector

Project Title:

Computer Modelling for Refinery Optimization

Objective:

To improve short-term planning and day-to-day operation of all refineries through computer modeling of key process units.

Scope

This project will include a review of current plant operations, feedstocks, yields and market demands in order to develop appropriate methodology for the application of computer modeling in Petroperu refineries. Following definition of the methodology and approach to be used, key process units are to be modeled, using actual plant data to modify generalized design correlations for the specific processes under consideration (catalytic reforming, fluid catalytic cracking, etc.)

Following the modeling effort, application of the models to optimization of day-to-day operations and to short-term planning will be implemented. A period of at least six months for this implementation phase is envisaged, partly to allow for thorough testing of the computer model approach and partly for training of local technical personnel. Subsequent to the training in Peru, it is suggested that additional training programs be arranged at selected U.S. locations to provide broader experience to Petroperu personnel, both in the use of models for short-term planning and operations control and in the use of models for long-term planning.

ITEM 3

Energy Option:

Maximum Coal Use

Project Title:

Increased Coal Utilization In Industry

Objective:

To define the potential for coal utilization in the industrial and mining sectors, identifying resource development requirements and end-use capital investment needs for implementation of an aggressive coal utilization program.

Scope:

Essentially all fossil fuel use in the industrial and mining sectors is petroleum-based and much of the electricity is generated by oil-fired boilers, kerosene-fired gas turbines or diesel generators. A major opportunity for the medium to long term therefore exists for the replacement of petroleum by domestic coal resources.

This project will include a thorough review of major industries with respect to the potential for use of coal in steam-raising and process applications. The review will identify technical constraints, and will document the economics of coal use in the various industries according to applications. The potential use of coal as a chemical feedstock will be included.

In order to promote coal utilization in industry, it will be necessary to identify the coal resource development requirements, in terms of the quantity and quality of coals, the nature of distribution facilities required, and coal conversion requirements for the end-use. Capital costs and manpower needs will be addressed, as will environmental issues which arise from the exploration of coal deposits and the use of coal by industry.

In addition to defining resource requirements, a program will be developed for meeting these requirements and providing the appropriate training for end-users. The scope of a follow-on effort to implement coal utilization will be developed.

Scope: (cont'd)

The effort will involve three parallel studies: a three year study of the coal resource base and necessary infrastructure, a one year study of industrial coal applications, and a program development effort in the third year. These studies and probable participants are illustrated below under "Peruvian Activities."

Total potential for coal substitution (i.e., oil savings) in the six major industries is estimated at 39.5 x 10^{15}J in the year 2000. Assuming 5% escalation annually in the world oil price, this amounts to $240 million. Total industry oil savings are estimated to be 56.4 x 10^{15} J in 2000, or about $343 million. These savings are detailed, by industry, in the accompanying exhibit.

Donor Activities:

These could include consulting assistance at all levels, particularly with regard to industrial applications. The need in the coal resource efforts will be for experienced geologists and mining engineers.

Peruvian Activities:

Peruvian participation in the three studies is envisioned to be as follows:

		Years	Participants
I.	Mines/seams/infrastructure	0-3	Energia y Minas, Mineroperu, Siderperu
II.	Industry study	1-2	Energia y Minas, Electroperu, Industria
III.	Program development	2-3	Energia y Minas

Resource Requirements:

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Peruvian Cost$	100	160	240			500
Donor Cost	100	400	200			700
Total	200	560	440			1200

Other requirements: (equipment, etc.)

Notes: Exploratory drilling costs are not included in the above figures.

EXHIBIT N-2

INCREASED COAL USE OPTION:

POTENTIAL OIL AND GAS SAVINGS BY 2000

Detailed information on the potential for fuel substitution in the mining, non-ferrous and manufacturing industry sectors is not currently available. However, an approximate estimate of the potential for increased coal use has been made as follows:

(1) Mining/non-ferrous metals

- Oil use for electricity generation in 1976 = 6.8×10^{15} J/year
- assume all this can be replaced by coal-fired systems by 2000
- process uses in 1976 accounted for 13.13×10^{15} J.
- assume no more than 10% of this can be replaced by coal (technical limitations), say 1.3×10^{15} J.
- for new plants (1976-2000), additional petroleum fuel use is projected to be 2579×10^{9} KCal.
- assume 10% of this consumption can be replaced by coal, say 1.1×10^{15} J
- total for this subsector = $6.8 + 1.3 + 1.1 = 9.2 \times 10^{15}$ J
- estimated dollar savings = $56 million

(2) Iron and Steel

- of petroleum fuel use, about 12% is for blast furnace injection
- by 2000, petroleum use amounts to 16.93×10^{15} J
- assume all blast furnace injection replaced by coal/coke by 2000
- savings are estimated to amount to 2.0×10^{15} J
- estimated dollar savings = $12 million

Cement

- in principle, all kiln fuel could probably be replaced by coal, limited only by environmental and economic factors
- assume 90% of fuel is in fact replaced by coal by 2000
- savings of oil amount to 26.6×10^{15} J
- estimated dollar savings = $162 million

Oil Refining

- assume about 20% of fuel use can be replaced by coal as a fuel for steam raising
- savings of oil amount to 4.4×10^{15} J
- estimated dollar savings = $27 million

Petrochemicals and Chemicals

- assume about 10% of fuel use is for steam raising which can be carried out using coal
- savings of oil amount to 1.2×10^{15} J
- estimated dollar savings = $7 million

Fertilizers

- data on Fertisa indicates 55% of petroleum fuel is used for electricity generation
- assume all of this can be replaced by coal by 2000
- savings amount to 2.1×10^{15} J
- estimated dollar savings = $13 million
- for urea manufacture, 59% of the natural gas is used for electricity generation and process fuel
- assuming 30% of the natural gas is for electricity generation, and all of this can be replaced by coal, savings of gas amount to 3.2×10^{15} J
- estimated dollar savings = $19 million

Total Industry Savings

- from the above, industry savings amount to

oil	38.3	$\times 10^{15}$ J
gas	3.2	
	39.5	

- estimated dollar savings = $240 million
- since "coverage" of identified industry subsectors is about 70%, potential savings are probably as follows:

oil	53.2	$\times 10^{15}$ J
gas	3.2	
	56.4	

- estimated dollar savings = $343 million

Total Mining/Non-Ferrous Savings

- these amount to 9.2×10^{15} J (as oil)

Increased Coal Use

- in the absence of specific data on relative efficiencies of oil, gas and coal use, it is assumed that direct replacement, joule for joule, is made.
- increased coal use amounting to 65.6×10^{15} J is therefore projected by 2000 under this option:

	Oil	Gas	Total
Industry	53.2	3.2	56.4
Mining/non-ferrous	9.2	-	9.2
	62.4	3.2	65.6

Donor Activities:

Peruvian Activities:

All Peruvian activities in this project should be coordinated by the Ministerio de Energia y Minas, with participation by the Ministerio de Industria, and by various agencies such as Petroperu, Siderperu, Induperu, Mineroperu and Centromin.

Resource Requirements:

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Peruvian Cost (8 people)	40	40	40	40	40	200
Donor Cost $	160	160	160	160	160	800
Total	200	200	200	200	200	1000

Other requirements: (equipment, etc.)

Notes:

ITEM 4

Energy Option:

End use energy efficiency improvement in the industrial sector.

Project Title:

Engineering Management Support for the Industrial Sector

Objective:

To support Peruvian manpower development efforts, with emphasis on middle management experience opportunities, in the industrial plant/process industry area.

Scope:

The manpower development efforts related to the industrial sector will provide on-the-job experience to Peruvian middle managers in the areas of cost/schedule control, project work scope development and implementation, project management, scheduling, cost reviews, technical reviews, and quality assurance. Particularly important will be training oriented to the analysis of energy use and industrial technologies in the context of new plant designs. The activity will extend over a period of five years. It will provide for from five to ten people per year to receive up to one year's experience oriented to manpower development activities. In addition, engineering management support would be provided on a consultation basis in response to specific requests. Products of this project will include reduced dependence on expatriates for middle management activities, and the exposure of Peruvian managers to a diversity of management styles and experience.

ITEM 5

Energy Option:

End Use Energy Efficiency Improvement in the Industrial Sector

Project Title:

Use of Waste Materials

Objective:

To Reduce Overall Energy Consumption In The Industrial Sector by Utilizing Waste Materials

Scope:

The project will provide an assessment of the potential for using waste materials in all industrial sectors. Examples include the use of blast furnace and other metallurgical slags in the manufacture of blended cements, the use of similar materials for aggregate production, and the use of steel plant slags as raw materials for glass fiber production. Included within this project should be the use of naturally-owing possolana in the manufacture of blended cements. Without detailed studies, energy savings are difficult to assess. However, a rough estimate may be based on the ultimate replacement of 25% of the energy used in manufacturing cement by the use of by-product slags. On this basis, savings by 2000 would amount to 8.1 x 10^{15} joules/year, with perhaps 2 x 10^{15} joules achieved by 1985.

Donor Activities:

Consulting assistance, e.g., to provide information on the state-of-the-art on the applications of waste materials. A three man team working, say, half-time for two years should be adequate.

Peruvian Activities:

Activities would be directed by the Ministerio de Energia of Mines, with participation by the Ministerio de Industria. An appropriate level of effort is estimated to be six engineers, working on say three specific areas of application.

Resource Requirements:

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Total Cost $ 10^3	30	30				60
Donor Cost $ 10^3	150	150				300
Total	180	180				360

Other requirements: (equipment, etc.)

Notes:

EXHIBIT N-3
SUMMARY OF THOUGHTS ON MAXIMUM ELECTRIFICATION STRATEGY

This strategy examines the implications of maximizing the use of electricity as an energy source for Peruvian industry. The overall issue may be split into two distinct areas: (1) conversion of existing fuel-intensive production capacity to hydroelectric-intensive processes, and (2) development of new industries whose process technologies demand an abundant supply of inexpensive electric power.

With respect to the first area (i.e., conversion), it should be noted that the reference projection for the year 2000 provides an estimate of 52.3×10^{15} J. of electricity required by industry, of which an estimated 11.3×10^{15} J. are self-generated. The remaining 41.0×10^{15} J. are, of course, supplied by public utilities. Of the 11.3 figure, 92% (or 10.4×10^{15} J.) are generated from oil at an assumed efficiency of 25%. If it is assumed that 90% of this power can be supplied from a hydro source, the resulting oil savings in the year 2000 total <u>37.4×10^{15} J.</u> The corresponding hydro output of 9.3×10^{15} J., at a load factor of say 65%, will require dedicated capacity of some 450 MW.

An additional significant oil savings, under the maximum hydro scenario, is likely to come from the mining and nonferrous metals industry sector. The reference projection includes an estimate of about 26×10^{15} J. of oil consumed in this sector for process use (i.e., uses other than for electricity generation) in the year 2000. A great deal of this fuel is used, for example, in copper smelters for the production of blister copper. However, competing technologies are available (and are in fact already used at existing sites within Peru) for the hydrometallurgical extraction of copper from ore. These process electrowin copper from the ore, as opposed to the pyrometallurgical separation accomplished in the smelter. It is estimated that perhaps 50% of existing pyro capacity can be converted by the year 2000, with a resulting oil savings of <u>13×10^{15} J.</u> Of course, dedicated hydro facilities would have to be available to allow for an equivalent production level.

The remaining potential for conversion to electricity is probably small on a relative basis. Some additional steel may be produced in induction furnaces, or glass in electric furnaces, but the other large industries such as petroleum refining and chemicals offer little potential. As discussed above, the largest impact will be felt in the conversion of existing oil-fired, self-generated industrial power, and the conversion of plants with oil-fired smelters and furnaces to alternative electricity-intensive processes.

The potential for electrification in the second area, development of new industries, is less clear and not quite as easily quantified. Of course, the primary question is to determine the amount and direction of the development to take place. At present, there is no concrete plan available for use as a basis in this analysis. Furthermore, the possibilities are many:

- production of electricity-intensive metals such as aluminum, magnesium, titanium, zirconium, etc.
- development of a steel industry based on pre-reduced iron ore.
- production of high value-added products, such as ferroalloys, which may require nearly 4 kWh/lb to produce.
- production of calcium carbide, used in acetylene production, in electric furnaces.
- expansion of nitrogenous fertilizer capacity based on nitrogen from air and hydrogen from water, as is presently done at Cachimayo.
- and many others.

These projects all share one common link: they are extremely electricity-intensive industries. However, the lack of a definite industrial development plan at this time renders it impossible to produce quantitative estimates of the power which will ultimately be required.

O. PUBLISHED DATA SOURCES

The most commonly used sources of data were the following:

1. "La Mineria en el Peru, 1977" (annual, volume 14) published by Editores Tecnicos Asociados S.A., Lima.
2. Minerals Yearbook 1973, U.S. Bureau of Mines ("The Mineral Industry of Peru").
3. "A Preliminary Assessment of the Energy Supply-Demand Situation in Peru", Brookhaven National Laboratory, Upton, N.Y. (Preliminary draft, June 1978).
4. Annual Minerals Report, 1977 (CERP 0429), produced by the American Embassy, March 15, 1978.
5. "Area Handbook for Peru, 1972", Foreign Area Studies of the American University, Washington, D.C.
6. "Anuario de la Mineria del Peru 1975", Ministerio de Energia y Minas, Lima.
7. "La Industria en el Peru", Ministerio de Industria y Turismo, March 1975 (prepared for the 2nd general assembly of the UNIDO).
8. "The Andean Report", July 1975 to date (published monthly in Lima).
9. "Oroya Metallurgical Operations, 1970", Cerro de Pasco Corp.
10. "Informe Anual 1975/1976/1977", Depto. de Electricidad y Telecommunicaciones, Centromin, Lima.
11. "Estadistica Petrolera del Peru, 1975", Ministerio de Energia y Minas, Lima.
12. "Estadistica Industrial 1975 - Manufacturas", Oficina de Estadisticas, Ministerio de Industria y Turismo, Lima.
13. "Indicatores del Sector Manufacturero, Enero-Diciembre 1977" (BEI-24), Oficina de Estadisticas y Registros, Ministerio de Industria y Turismo, Lima.
14. "Proyectos de Inversion Industrial 1977", Oficina Sectorial de Planificacion, Ministerio de Industria y Turismo, Lima.
15. "Estadistica Anual de Electricidad 1975/1976", Ministerio de Energia y Minas, Lima.
16. "Plan Operativo 1977-1978/1978-1979"; Ministerio de Agricultura y Alimentacion.

P. LIST OF MEETINGS ATTENDED

In order to collect data on current activities, planned projects, and energy consumptions, the following meetings were conducted:

June	Office/Agency	Persons Contacted
16	International Executive Service Corps.	Jim Winkelman (Director)
19	Oficina Sectoral de Planificacion, Ministerio de Agricultura y Alimentacion	Luis Paz
20	Ministerio de Energia y Minas	Jorge Aguinaga (Peru study coordinator) Ing. Haro
20	Oficina Sectoral de Planificacion, Area de Planificacion de Mineria, Ministerio de Energia y Minas	Juan Amayo Humberto Vasquez
20	Division de Estudios Tecnico-Economicos Minero Peru	Tomas Guerrero Mariano Iverico (Gerente Proyectos) Jaime Mercado (Gerente de Div. de Estudios Tec. Econ.) Ing. Lescano
22	Incitemi (Instituto Cientifico y Mineralogico Minero)	Cesar Sotillo Palomino (Director General) Hugo Palomino Glener
22	Agricultural Attache, U.S. Embassy	Richard L. Barnes (Attache) Lucho Arese
22	Ministerio de Energia y Minas	Ricardo Saettone Dodds (Deputy Minister)
23/23	Oficina de Proyectos, Ministerio de Industria y Turismo	Godofredo Ramirez (Directo de Proyectos) Victor Gonzalez Carbajal
26	Division Central de Planeamiento, Centromin	Lew Gallardy Renato Gibellini (Coordinator de Proyectos
27	Oficina de Planeamiento, Petroperu	Jose Miguel Carrasco (Coordinator de Planeamiento)
27	Siderperu	Rodolfo Bragagnini (Director Tenico)

28	Apoyo S.A. ("Peru Economico")	Felipe Ortiz de Zevallos (Editor)
28	Piazza y Valdez Inginieros S.A.	Jose Valdez (President)
30	Oficina Sectorial de Planificacion de Alimentacion, Ministerio de Agricultura y Alimentacion	Marco Hidalgo
30	Plant Visit, La Pampilla Refinery, Petroperu	Carlos Repeto (Gerente) Donald Salazar Ruiz (Director Tenico) Ing. Barredo Tamayo
30	Oficina de Planificacion de Energia, Ministerio de Energia y Minas	R. Montalvan (Director) Jorge Aguinaga (Peru Study Coordinator)

August (Plant Visits)

8 Cementos Lima (Atocongo)

8 Metinsa (metal fabrication, tubes, sheet, fittings, etc.)

10 Backus and Johnston Brewery (Rimac)

11 Quimica del Pacifico (Callao)

11 Pescaperu fishmeal plant (Callao)

14 Fertisa fertilizer and chemical complex (Callao)

15 Paramonga complex (Sugar Cooperative, paper plant, chlorine/caustic, PVC)

Brookhaven review period

August 28-September 8	Options review and report development in conjunction with Peruvian counterparts (at Brookhaven National Laboratory).

ANNEX - 3

REPORT ON THE TRANSPORT SECTOR OF PERU

BY

PETER SMITH

ARTHUR D. LITTLE, INC.

U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

SEPTEMBER, 1978

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THE TRANSPORT SECTOR IN PERU

I. INTRODUCTION

The purpose of this paper is to provide background information to support estimations of energy requirements for the transport sector; also, to help determine the energy implications of various options open to the Peruvian Government of supplying transport infrastructure necessary to meet future demand for movement of freight and passengers within the country.

Based on the limited amount of data available on the transport sector in Peru and on interviews with knowledgeable persons in both the private and government sectors, it has been possible to get together a scenario describing the actual transport sector in the base year for this study (1976) and make projections of future transport activity. A major aid in this work has been the existence of the National Transport Plan, 1977-1986, (PDT) made available to the team by the Ministry of Transport and Communications. All numbers in this report have been derived from official Peruvian documents or as a result of conversations with government officials. They are best estimates of likely activity, given officially expected growth trends and the existence of, in some cases, a very limited data base. The projections are in no way to be considered prophecies, but merely rough indications of orders of magnitude from which some useful conclusions can be made.

II. THE TRANSPORT INFRASTRUCTURE

A. The Road Network

In 1976 Peru had a road system totalling 56,940 kilometers of which 5,949 kilometers were paved, equivalent to 10.4% of the system. The road network density was only 0.04 kilometers/square kilometers of national land area. The Panamerican Highway which runs along the coastal plan from the Ecuadorean border in the North to the Chilean border in the South is paved in its entirety. Maintenance of the road network has been inadequate for several years. We were informed that until 1970-71, regular maintenance was carried out on most roads but that since then, only about 50% of the required funds for maintenance has been available annually. A recent study estimated that $US200 million would be needed to rehabilitate the road system to a level where routine maintenance could preserve acceptable road conditions; about 5-10% of the country's roads are in a desperate state of disrepair.

B. The Rail Network

There is a total of 2,545 kilometers of track of which 1,933 kilometers is owned by the public sector, under the administration of the Empresa Nacional de Ferrocarriles del Peru (ENAFER). Over 80% of the track length is standard gauge (1.435 meters). Rail links penetrate the interior of the country. There is no coastal railway. The two main sectors are the Central Railway which joins Callao-Lima to the Central mining areas, and the Southern Railway which starts at the coast at Matarani and goes inland to Cuzco and Chaullay. A project currently underway is to extend the Southern Railway by connecting Puno on Lake Titicaca with Desaguadero on the Peruvian-Bolivian border.

C. Airports

According to the PDT, three airports--Lima, Pisco, Talara--were classified in 1976 as first-class, capable of handling aircraft of Boeing 707 class. Eight further airports were capable of handling aircraft of Boeing 727 class. The total number of registered airports in 1975 was 244. In addition, there are 87 areas allocated for seaplane landing.

D. Seaports

Of the 28 classified seaports in the country, 12 had facilities which, in 1976, allowed ships to tie up alongside a wharf. Ten of these are located on the Pacific Coast, one (Iquitos) on the Amazon, and the other (Puno) on Lake Titicaca. The Port of Callao, serving the Lima area, can accommodate vessels up to 9.75 meters draft and has 22 berths at four finger piers, each pier averaging 183 meters in length. The most important cabotage ports are Talara (distribution of petroleum products), San Nicolas (distribution of iron ore), Chimbote (receipt of iron ore), Iquitos (general cargo) and Callao. The principal export ports are Callao and La Pampilla (petroleum).

E. Urban Infrastructure

Lima is, by far, the most important urban area in the country; urban passengers and freight move by road. One rail line passes through the city, connecting the coast with the Sierra region. There is one major expressway with "bus only" lanes in the center connecting Miraflores with the town center. Several boulevards are wide but the majority of roads are narrow, permitting only one-way traffic. Congestion is serious in several parts of the city.

III. TRANSPORT VEHICLES

A. Road Vehicles

It has been estimated that the total road vehicle population in Peru is about 464,000 units of which approximately two-thirds are registered in the Department of Lima. In 1976, there were approximately 270 vehicles per 10,000 inhabitants or 37 habitants for each vehicle. Domestic automotive assembly operations turned out 34,344 vehicles in 1976, of which 26,290 were automobiles and station wagons. Since that time, there has been a drop in the number of domestically-assembled vehicles corresponding to the economic difficulties experienced in the country. Rough calculations indicate that the average automobile travels approximately 12,000 kilometers per year. The category "automobile" includes taxis and colectivos. The motorcycle population is approximately 47,000 of which 64% is registered in the Department of Lima.

It is estimated that in 1976 about 23,000 buses operated in the country of which 10,000 were microbuses. About 9,300 buses operated in urban centers, 7,900 of these in Lima. The remaining 13,700 buses are engaged in rural or intercity transport. The average urban bus is believed to operate approximately 30,000 kilometers per year and the average rural and intercity bus is estimated to travel 12,000 kilometers per year. There are about 61,000 trucks in the country, only 40% of which are registered in the Department of Lima. It was assumed, based on the limited evidence available, that the average truck travelled 15,000 kilometers per year and carried an average load of just over six tons. Energy intensity of trucks is very high, reflecting poor road conditions and difficult terrain in the Sierra region.

Light vans, mostly carrying out service functions, total 62,000, of which 55% are registered in the Department of Lima. It was assumed that in 1976 these vehicles travelled an average of 15,000 kilometers per year which, given that they operate generally in urban traffic conditions and remain parked for some of the working day, may not be an unreasonable assumption.

An estimation of the road vehicle fleet in 1976 is shown in Table 1.

B. Railroad Rolling Stock

The two main railroads, which operate under the government-controlled ENAFER, have a total of 107 locomotives of which 74 are diesel electric. Rolling stock includes 2,008 freight and 190 passenger cars.

The Lake Titicaca steamship service, which includes one train ferry, five passenger-freight vessels, is also operated by ENAFER.

C. Aircraft

Of the 145 aircraft registered in Peru in 1976, 15 were jet-propelled, six turbo-propelled and 124 propeller planes. Twenty-seven aircraft were maintained on regularly-scheduled flights--14 of these were jet-propelled.

D. The Maritime Fleet

The Peruvian ocean-going merchant fleet in 1976 consisted of 39 vessels of which 15 were under private ownership and 24 belonged to the state. Seven of the 39 ships are less than five years of age. In the Table below, it can be seen that the average deadweight tonnage (a measure of the carrying capacity of a vessel) of bulk carriers indicates that these vessels are capable of participating in the long-haul export and import trade of the country. Most tankers would be engaged in cabotage along the coast. The general cargo vessels operate in liner services on international routes (see Table 2).

TABLE 1

ESTIMATED AUTOMOTIVE FLEET: 1976
(Thousands of Vehicles)

Type	Total Country	%	Department of Lima	%	Department of Lima As % of Country
Motorcycles	47	10	30	10	64
Cars	271	58	203	66	75
Microbus	10	2	8	3	75
Omnibus	13	3	7	2	50
Light Vans	62	14	34	11	55
Trucks	61	13	24	8	40
TOTAL	464	100	306	100	66

Source: Update of Table in Metro-Lima Study.

TABLE 2

PERUVIAN MERCHANT FLEET:[1] 1976

Type	Number of Vessels: Private	Number of Vessels: State	Number of Vessels: Total	Deadweight Tonnage	Average Deadweight/ Vessel
General Cargo	8	14	22	251,735	11,443
Bulk Carrier	6	3	9	258,215	28,691
Tanker	1	7	8	116,699	14,587
TOTAL	15	24	39	626,649	16,068

[1] Excluding lake and river vessels.

Source: Ministry of Transportation.

There are six vessels registered for operation on Lake Titicaca and a total of 6,088 vessels of small size registered in the Ports of Iquitos, Pucallpa and Yurimaguas which operate in the Amazon River system.

IV. TRAFFIC

A. Road

It is estimated in the PDT that road freight traffic accounts for almost 50% of all domestic freight in terms of ton-kilometers (see Table 3). Road is especially important for agricultural products. Road accounts for 94.8% of ton-kilometers of agricultural products and 83.7% of ton-kilometers of industrial products. Domestic movements by road of minerals and oil are relatively unimportant compared to other modes.

Although the proportion of ton-kilometers by road in each of the sectors is expected to increase by 1986, because of the very large amount of oil by cabotage, in absolute terms, road becomes less important and is expected to account for 41.8% of total domestic freight ton-kilometers. Road remains the dominant mode of transport for agriculture and industrial goods in 1986.

The average annual growth rate of ton-kilometers by road over the period 1976-1986 is expected to be 5.33%.

As seen in Table 4 road is the dominant mode of transport for both intra-inter-regional passenger travel within Peru. The only areas in which serious competition is met from other modes are in the South, where there is significant rail passenger traffic, and between the Center and Southern regions, where air services are important.

No forecast is made in the PDT concerning the entire inter- and intra-regional passenger network, but projections are made for 1986 for a reference network in which a breakdown is given of the passenger-kilometers expected of each of the modes.

TABLE 3

PERU: INTER-CITY ROAD FREIGHT--1976 AND 1986

	1976			1986			1987-1986
	Ton-Kilometers x 10^6	% of Sector by Road	% of All Road Freight	Ton-Kilometers x 10^6	% of Sector by Road	% of All Road Freight	% Average Annual Growth
Agriculture	2,373.6	94.8	42.7	4,519.6	95.1	48.4	6.65
Industry	2,860.9	83.7	51.5	3,733.9	85.7	40.0	2.70
Mining	94.0	9.5	1.7	426.5	14.6	4.5	16.33
Hydrocarbons	228.1	5.2	4.1	661.3	6.4	7.1	11.23
Fishery	--	--	--	4.0	100.0	--	--
TOTAL	5,556.6	49.2	100.0	9,341.7	48.1	100.0	5.33

Source: Plan Director de Transportes, 1977-1986.

TABLE 4

PERU: INTER-CITY PASSENGER MOVEMENTS BY ROAD--1976

Intra-Region	Thousands of Passengers	Millions of Passenger Kilometers	Kilometers/ Passenger	Road[1] % of all Modes Passengers	Road[1] % of All Modes Passengers/Kilometers
North	1,657.9	487	293.75	99.2	99.6
Center	2,516.0	1,477	587.04	85.5	90.3
South	1,227.0	497	405.05	54.3	57.1
East	--	--	--	--	--
Subtotal	5,400.9	2,461	455.66	79.7	81.2
International					
Center-North	2,060.9	1,453	705.03	87.9	88.5
Center-South	886.9	355	400.27	65.9	53.0
Subtotal	2,947.8	1,808	613.34	74.7	71.5
TOTAL	8,348.7	4,269	511.34	76.6	76.8

[1] National traffic only.

Source: Plan Director de Transportes, 1977-1986.

For that reference network within the Northern Region, it is expected that road will account for practically all passenger-kilometers in 1986. In the Central Region, rail and air are expected to become more important and in the Southern Region, road will lose some of its importance to rail.

Between the Northern and Central Regions, it is expected that rail will account for 74.6% of passenger-kilometers, utilizing a coastal rail link to be constructed and air will account for 20.5%, leaving only 4.9% for road on this inter-regional route. With new roads to penetrate the Eastern Region from the Northern Region, road will account for 84.8% of that inter-regional traffic. Between the Central Region and the South of the country, it is anticipated, in the PDT, that road's share of passenger-kilometers will remain similar to that in 1976.

B. Rail

In 1976, according to the PDT (see Table 5), rail accounted for about 9.1% of all inter-city freight ton-kilometers. Rail is most significant in the mineral sector where 35.8% of ton-kilometers were accounted for by this mode. On certain links rail is clearly the dominant freight mode; for example, between Callao-Lima and La Oroya and La Oroya and Cerro de Pasco on the Central Railway and between Arequipa and Puno and Puno and Cuzco on the Southern Railway. It is expected that rail will remain important over these links in 1986. The total share of rail of national ton-kilometers is, however, projected to drop to 6.6% by 1986.

It is only in the Southern Region that rail passenger traffic is competitive in terms of numbers of passengers and passenger-kilometers, where 43.8% of all passengers and 41.7% of passenger-kilometers in the Region are accounted for by rail (see Table 6).

TABLE 5

PERU: INTER-CITY RAIL FREIGHT--1976 AND 1986

Sector	Ton-Kilometers x 10^6	% of Sector by Rail	% of All Rail Freight	Ton-Kilometers x 10^6	% of Sector by Rail	% of All Rail Freight	Average Annual Growth Rate: 1976-1986
Agriculture	102.7	4.1	10.0	180.6	3.8	12.2	5.81
Industry	389.7	11.4	37.8	496.7	11.4	33.6	2.46
Mining	354.4	35.8	34.3	476.2	16.3	32.6	3.00
Hydrocarbons	185.1	4.2	17.9	322.6	3.0	21.9	5.71
TOTAL	1,031.9	9.1	100.0	1,476.1	6.6	100.0	3.64

Source: Plan Director de Transportes, 1977-1986.

TABLE 6

PERU: INTER-CITY PASSENGER MOVEMENTS BY RAIL--1976

Inter-Regional	Passengers (Thousands)	Passenger/ Kilometers (Millions)	Kilometers per Passengers	Rail Passengers % of Total	Rail Passengers/Kilometers % of Total
Central	249.1	83	333.2	8.5	5.1
Southern	989.2	363	367.0	43.8	41.7
TOTAL	1,238.3	446	360.2	11.4	8.0

Source: Plan Director de Transportes, 1977-1986.

For the 1986 reference network, rail passenger movements will continue to be significant in the Southern Region, expected to account for 47.5% of passenger-kilometers. In inter-region passenger services rail will assume a dominant role (74.6% between the North and Central Regions), following the planned introduction of a coastal rail link north from Lima.

C. Air

In 1976, domestic air freight totaled about 90,000 tons--equivalent to 90-million ton-kilometers. Most cargo is carried on passenger flights. The PDT does not record air cargo as a major item and as it is a joint product with passenger services, energy requirements can be derived by examination of passenger movements alone without too much chance of error. Although not included in the Reference Case, it is conceivable that a significant number of all-cargo flights will be operating by 2000, especially between Eastern areas and the urban centers in the West. Some of this may be by nonconventional means as mentioned later in this report.

According to the PDT (see Table 7), 1.3 million passengers flew on domestic services in 1976--equivalent to 844 million passenger-kilometers. Air accounted for 12% of all inter-city passenger movements within the country and 15.2% of passenger-kilometers. Air is especially important within the Eastern Region and between the Eastern Region and Central and Northern Regions serving as the only link in many cases.

The reference network for 1986 suggests that air traffic will continue to be the sole mode of passenger traffic between centers in the Eastern Region and between the Central and Eastern Regions. Even with the new rail link along the coast joining the Central and Northern Regions, which is expected to be operational by 1986, it is anticipated that the percentage of passenger-kilometers by air will increase from 11.5% to 20.5%, at the expense of road

TABLE 7

PERU: INTER-CITY PASSENGER MOVEMENTS BY AIR--1976

Region	Passengers (Thousands)	Passengers Kilometers (Millions)	Kilometers Per Passenger	Air Passengers % of Total	Air Pass/Kms % of Total
Inter Regional					
North	13.1	2	152.7	0.8	0.4
Center	177.1	76	429.1	6.0	4.7
South	43.3	10	231.0	1.9	1.2
East	75.8	34	448.6	100.0	100.0
Subtotal	309.3	124	400.9	4.5	4.1
Inter-Regional					
Center-North	283.7	188	662.7	12.1	11.5
North-East	34.3	11	320.7	100.0	100.0
Center-South	459.7	315	685.2	34.1	47.0
Center-East	223.1	206	923.4	100.0	100.0
Subtotal	1,000.8	720	719.4	25.4	28.5
National	1,310.1	844	644.2	12.0	15.2
International	704.7			100.0	
TOTAL	2,014.8			17.4	

passenger traffic. The portion of passenger-kilometers between the Central and Southern Regions is expected to remain similar in 1986 to that in 1976.

D. Maritime

At the present time, cabotage is restricted to minerals, which move between San Nicolas and Chimbote, and petroleum and products. Although the table of the PDT showing ton-kilometers by sector and by mode of transport for 1986 indicates that only these two sectors will supply cargo to cabotage shipping (Table II-4 of the PDT), an examination of projected movements through ports in 1986 suggests that fertilizer originating in Talora-Bayovar and general cargo might be expected to move in the cabotage trade. Restricting the discussion to the mineral and hydrocarbon sectors, ideal commodities for cabotage movement, it is expected that the shipping share of domestic cargo in terms of ton-kilometers will rise for minerals from 54.7% to 62.1% and remain the same for petroleum and products. Overall cabotage ton-kilometers are expected to grow at an annual rate of 9.7% over the period 1976-1986 (see Table 8).

Amazon River traffic is only expected to grow modestly--by 0.6% per year--through the period 1976-1986 (see Table 9), reflecting the introduction of road links in the Eastern Region which will permit some direct road transport from the central and coastal parts of the country.

E. Urban Passenger Movements

The Metro-Lima Study, completed in late 1973, estimated that by 1976 4.1 million journeys per day would be made in the Metropolitan Lima area with an average length of journey being 7.75 kilometers (see Table 10). By 1992, 2.6×10^9 annual journeys would be taken and the average distance increased to 11.6 kilometers, reflecting a remarkable expansion in the size of the city

TABLE 8

PERU: CABOTAGE FREIGHT--1976 AND 1986

	1976			1986			
Sector	Ton-Kilometers x 10^6	% of Sector by Sea/River	% of All Sea/Freight	Ton-Kilometers x 10^6	% of Sector by Sea River	% of All Sea Freight	Average Annual Growth Rate 1976-1986
Mining	541.4	54.7	12.1	2,018.6	62.1	17.9	14.1
Hydrocarbons	3,921.5	89.5	97.9	9,234.2	89.5	82.1	8.9
TOTAL	4,462.9	39.5	100.0	11.252.8	50.4	100.0	9.7

Source: National Transport Plan, 1977-1986 (PDT).

TABLE 9

PERU: RIVER FREIGHT--1976 AND 1986

Agriculture	27.5	1.1	11.3	52.3	1.1	20.3	6.6
Industry	167.5	4.9	69.1	126.4	2.9	49.0	-2.8
Hydrocarbons	47.5	1.1	19.6	79.0	0.1	30.7	5.2
TOTAL	242.5	2.2	100.0	257.7	1.2	100.0	0.6

Source: National Transport Plan, 1977-1986 (PDT).

TABLE 10

URBAN PASSENGER FORECASTS: LIMA--1972-1979

	Daily Journeys (Thousands)	Length Each Journey (Kilometers)	Daily Passenger-Kilometers (Thousands)
1972	3,046	6.70	20,408
1973	3,313	6.96	23,068
1974	3,580	7.23	25,866
1975	3,847	7.49	28,806
1976	4,114	7.75	31,884
1977	4,381	8.01	35,105
1978	4,648	8.28	38,462
1979	4,915	8.54	41,964
Average Annual Growth--%	7.07	3.53	10.85

Source: Metro Lima Study.

and the greater distance that people would have to travel to work and on their daily affairs. Annual passenger-kilometers by public transport is expected to grow at a rate of 8.3% per year over the 20-year period (see Table 11).

No information was available about passenger movements in urban areas outside of Lima or freight movements in any urban areas of Peru.

TABLE 11

URBAN PASSENGER FORECASTS: LIMA--1972-1992

	Annual Journeys x 10^9	Length Each Journey (Kilometers)	Annual Passengers/Kilometers x 10^9
1972	914	6.7	6,124
1976	1,234	7.8	9,625
1980	1,555	8.9	13,840
1984	1,901	9.8	18,630
1988	2,246	10.7	24,032
1992	2,592	11.6	30,067
Average Annual Growth--%	3.35	2.78	8.28

Source: Metro Lima Study.

V. PLANS FOR TRANSPORT INFRASTRUCTURE AND VEHICLES

A. Road

In the PDT the reference long-term road transport network for 1986 is designed to be capable of handling 3,950 million ton-kilometers of freight and the corresponding road transport fleet would have a "static" capacity of 74.9 thousand tons. To effectively complete the reference system, a program for highway construction and improvement is presented in the PDT (see Table 12).

In order to handle the projected ton-kilometers of road traffic over the basic network, it is expected that additional road vehicles will be necessary by 1986 (see Table 13).

B. Rail

To handle the cargo assigned to the rail network in 1986, it is anticipated that the lines listed in Table 14 will have to be constructed.

TABLE 12

ESTIMATED CONSTRUCTION AND IMPROVEMENT
OF CURRENT HIGHWAYS IN THE PERIOD 1977-1986

(Kilometers)

Region	Asphalt	"Afirmado" (Secondary Roads)	Total Kilometers
Northern	577	213	790
Central	903	641	1,544
Southern	445	296	741
Eastern	-	134	134
TOTAL	1,925	1,284	3,207

Source: PDT.

TABLE 13

VEHICLE ADDITIONS TO HANDLE 1986 ROAD FREIGHT TRAFFIC OVER REFERENCE NETWORK

Vehicle		Number Required
Truck	30-ton "Coastal" Traffic	1,170
Truck	10-ton "Sierra" and "Selva" Traffic	3,970
Bus	40 Passengers Capacity	1,720

Source: PDT.

TABLE 14

PROJECTED RAIL CONSTRUCTION: 1977-1986

Link	Length (Kilometers)
Lima-Trujillo	590
Huacho-Cerro de Pasco	325
Ramal Caripa-Tarma	60
Ilo-Matarani	100
TOTAL	1,075

Source: PDT.

As shown in Table 15, in addition to an unrecorded number of diesel electric locomotives of from 600 HP to 3,000 HP, rolling stock will also be necessary to meet the prescribed transport goals of the PDT.

C. Air

To accommodate the expected flow of domestic passengers by 1986, new airports are proposed for Huancayo and Puerto Maldonade and improvements made at Tumbes, Piura, and Chiclayo in the Northern Region, Jorge Chavez in the Central Region, Arequipa, Juliaca, and Tacna in the Southern Region and at Iquitos, Pucallpa, and Tarapoto/Yurimaguas in the Eastern Region. In addition, it is proposed that navigation aids be installed and improvements made to warehouses, terminals and other installations in several of the country's airports. It is also anticipated that the domestic airline fleet will have to be expanded by 10 jet aircraft of 120 passenger capacity for routes of lengths greater than 600 kilometers and four jet aircraft of 60 passenger capacity for routes less than 600 kilometers in length.

D. Maritime

To handle domestic and international waterborne traffic new ports are proposed in the PDT at Huacho (for minerals) and Pucallpa and Yurimaguas (river traffic) and new wharves at Bayovar (phosphates), Chimbote (general cargo, concentrates), Puerto Maldonado, Ayer Manco, Atalaya (embarcation landings for river traffic). In addition, improvements and extension of wharves and construction and improvement of transit sheds and other installations are recommended at Talaro, Eten, San Martin, Matarani, Puno, Iquitos, Salovery, Ilo, and others. It is also recommended that appropriate cargo-handling equipment be acquired as necessary.

To carry out the projected coastal and river cargo, it is proposed that additional vessels be added to the domestic fleet (see Table 16).

TABLE 15

RAIL ROLLING STOCK PLANNED ACQUISITION
(1977-1986)

Vehicle	Description	Number Required
Freight Wagon	Special Purpose 40-60 Tons Capacity	1,100
Freight Wagon	General Cargo 40-60 Tons Capacity	1,200
Passenger Car	70 Seats	155
Passenger Car	100 Seats	245

Source: PDT.

TABLE 16

VESSEL ACQUISITIONS TO PERUVIAN DOMESTIC FLEET
(1977-1986)

Services	Vessel Type	Size (DWT)	Number Required
Cabotage	Tankers	58,000	1
Cabotage	Tankers	26,000	3
Cabotage	Tankers	Not stated	17
Cabotage	Ore carriers	25,000	2
Cabotage	Grain carriers (fertilizers)	7,500	2
Cabotage	Pallet ships (rice, sugar)	4,800	2
Cabotage	General cargo	10,000	1
River	Tankers	100	10
River	General cargo	1,000	2
River	General cargo	400	8

Source: PDT.

E. Urban Transport

This discussion is confined to Lima and, in particular, to the suggested Metro system of 70 kilometers in length with 1992 being the target year for implementation of the network. There would be four main lines with the first between Comas and El Salvador being 36.8 kilometers in length. The proposed system would relieve the congestion problems likely to face surface transport. The plan called for a simultaneous rationalization of surface transport by reallocating routes, forming transport companies to replace individual operations, and obtaining appropriate buses that would feed the Metro system and serve as a complementary form of public transport.

The Metro would be a conventional two-rail system with steel wheels on steel tracks (rubber tires require approximately 50% more energy to perform the same transport service). It was envisaged that trains would be composed of six coaches of a total length of 128 meters and a width of 3.07 meters. The maximum speed would be 90 km/hr and the average speed over a journey of 37 km/hr. To complement the full 70-kilometer system there would be a "rationalized" bus fleet of 9,300 vehicles by 1992.

VI. ENERGY REQUIREMENTS FOR THE TRANSPORT SECTOR

This section discusses the energy requirements of transport vehicles and does not look at the energy requirements needed to build transport infrastructure, which would involve detailed knowledge of materials used and techniques employed for each project--well beyond the scope of the current terms of reference.

A. Roads

1. Automobiles

Estimates have been made by the team, based on gasoline sales of PetroPeru and an estimated breakdown of these sales among various categories of vehicles.

An activity level of 3.25×10^9 vehicle-kilometers was established for automobile traffic in 1976. With an automobile stock of 271,000 units, this implies that each vehicle travels 12,000 kilometers per year. Comparable figures for the United States are 15,276 kilometers per vehicle (1976) and 14,300 kilometers in the United Kingdom (1972).

We estimate that average energy intensity for automobiles in Peru is 6.65×10^6 J/vehicle-kilometer. United States urban experience is approximately $5.31 \text{ J} \times 10^6$ per passenger-kilometer and for inter-city automobiles $2.3 \text{ J} \times 10^6$ per passenger-kilometer. United Kingdom experience is $1.6 \text{ J} \times 10^6$ per passenger-kilometer for inter-city and $3.1 \text{ J} \times 10^6$ per passenger-kilometer for urban driving.

2. Buses

The PDT estimates that inter-city passenger traffic was 4.27×10^9 passenger-kilometers in 1976. There is no breakdown between buses and other automotive travel. The Metro Lima study projected 9.63×10^9 passenger-kilometers for public transport in Lima for 1976.

Based on the ratio of buses in other urban centers to those for Lima and taking the same amount of passenger-kilometers per vehicle per year for those centers as for Lima, it is estimated that public transport in other urban centers amounted to 1.64×10^9 passenger-kilometers in 1976.

We have assumed, in the absence of any evidence, that 10% of inter-city passenger-kilometers are by automobile. Approximately 12% of public transport vehicles in urban centers are colectivos. Average passengers per colectivo, however, can be assumed to be approximately 10% of that of buses and it is estimated that only about 1.2% of public transport passenger-kilometers in cities would be accounted for by colectivos. This has been allowed for in the calculation of bus passenger-kilometers (see Table 17).

Energy intensity for urban buses in the United States in the 1950's was 0.76×10^6 J/passenger-kilometers. In the United Kingdom in the 1970's a 70-passenger double-decker bus used 0.8 MJ/passenger-kilometer.[1] Inter-city buses in the United States in the 1970's showed energy intensities of 1.11 MJ/passenger kilometer and in the United Kingdom 1.4 MJ/passenger-kilometer. We have used an intensity value of 1.0 MJ/passenger-kilometer to reflect Peruvian conditions. Factors which would lead to high energy intensity for the Peruvian situation would be:

a. The predominantly urban concentration of buses (two-thirds of passenger-kilometers are in urban areas); and

b. The poor road surface on inter-city routes.

[1] One MJ = $J \times 10^6$.

TABLE 17

BUS PASSENGER-KILOMETERS--1976 (x 10^9)

Inter-city	3.84
Lima	9.51
Other Urban	1.62
TOTAL	14.97 x 10^9 passenger-kilometers

On the other hand, the average load factor would be higher than in the United States or the United Kingdom.

3. Truck (Freight)

The Ministry of Transport and Communications (MOTC) estimates road freight in 1976 at 5.86×10^9 ton-kilometers. On the assumption that negligible freight movements went by bus, this figure is accepted as the freight movement by truck. As information about urban freight movements does not exist in Peru, this may underestimate total freight movement. The high level of energy intensity for freight truck (7.20×10^6 J/ton-kilometer) reflects poor road conditions and difficult terrain on inter-city routes.

4. Truck (Non-Freight)

This is assumed to be predominantly that movement confined to light vans. On the assumption that the entire light-van population is comprised in non-freight movements and travels an average of 15,000 kilometers per year, which is reasonable given that these vehicles are predominantly involved in urban areas and are parked for considerable periods of the working day, it is estimated that 9.3×10^8 vehicle-kilometers per year were performed by this category of vehicle.

The energy intensity appears reasonable for Peruvian conditions.

5. Motorcycles

It is estimated that the average motorcycle travels 10,950 kilometers per year and has an energy intensity of 0.94 J/vehicle-kilometer.

B. Rail

1. Freight

The PDT estimates 1.03×10^9 ton-kilometers performed by the railways of the country in 1976, including the private railways. The energy intensity per ton-kilometer is about double recent U.S. inter-city experience. The difficult terrain justifies this high intensity.

2. Passenger

MOTC estimates that rail passenger performance in 1976 was 5.28×10^8 passenger-kilometers.

The energy intensity used by the team is between the U.S. experience in the mid-1970's for inter-urban rail (1.97 MJ/passenger-kilometer) and the U.K. experience (1.0 MJ/passenger-kilometer).

Difficult terrain would suggest a higher intensity than U.S. or U.K. experience, but higher load factors significantly reduce the intensity per passenger-kilometer.

C. Air

MOTC reports 868×10^6 passenger-kilometers flown on domestic routes. In addition, domestic airlines accounted for 490×10^6 passenger-kilometers on international routes. Some foreign airlines fuel in Peru although the pricing system currently discourages this. The fuel consumption for the air mode in 1976 was estimated from sales figures for aviation fuels by PetroPeru.

D. Maritime

The PDT indicated 4.71×10^9 ton-kilometers of coastal and river shipping performed in 1976. Most of this is cabotage movement of liquid and dry bulks, an efficient operation that has low relative energy intensity. The U.S.

coastal and waterways experience in the early 1970's was 0.46×10^6 J/ton-kilometer. A similar figure should apply to the Peruvian situation.

The Peruvian international fleet is relatively small and would only obtain half or less of its bunkers in Peru. Foreign shipping, although facing an uncompetitive price, can obtain bunkers at Talaro and Callao.

The estimate for this mode is based directly on bunker sales of diesel, intermediate fuel oil, and bunker "c" given by PetroPeru.

Tables 18 and 19 summarize respectively transportation activity levels and energy intensity for each mode and total transportation energy consumption by mode for 1976.

TABLE 18

TRANSPORTATION ENERGY CONSUMPTION BY MODE--1976
(10^{15} Joules)

Mode	Consumption	% Sectoral Total
Truck	44.2	40.1
Automobile	22.1 [a)]	20.0
Air	13.6 [b)]	12.3
Ship	13.5 [c)]	12.3
Bus	15.0 [d)]	13.6
Railroad	1.9 [e)]	1.7
TOTAL	110.3	100.0

TABLE 19

TRANSPORTATION ACTIVITY LEVELS AND ENERGY INTENSITY BY MODE

Mode	Activity Unit	1976 Activity Level x 10^9	Energy Intensity Joules x 10^6 per Activity Unit
Automobile	Vehicle-Km	3.25[a)]	6.65[g)]
Motorcycle	Vehicle-Km	0.52[b)]	0.94[h)]
Bus	Passenger-Km	14.97[c)]	1.00[i)]
Truck (Freight)	Ton-Km	5.86[d)]	7.20[j)]
Truck (Non-Freight)	Vehicle-Km	0.94[e)]	2.16[j)]
Rail (Freight)	Ton-Km	1.03[f)]	1.10[k)]
Rail (Passenger)	Passenger-Km	0.53[d)]	1.57[l)]
Air	Passenger-Km	1.36[d)]	N.A.[m)]
Ship	Ton-Km	4.71[f)]	N.A.[m)]

NOTES TO TABLES 18 AND 19

Transportation Energy Consumption By Modes: 1976

a) Includes motorcycles.

b) Includes sales to foreign aircraft.

c) Includes bunkers to foreign vessels.

d) Inter-city and urban.

e) Includes private rail lines.

Transportation Activity Levels and Energy Intensity by Mode

a) Based on estimates of vehicle fleet and assumption of 12,000 kms. per vehicle per year.

b) Based on estimates of motorcycle fleet and use of 30 kms. per day.

c) Inter-city from National Transport plan (PDT) less estimated 10% for automobile inter-city passenger-kms.

Urban Lima from Metro-Lima study less 1.2% for colectivos.

Other urban from estimate of urban bus fleet.

Outside Lima and proportioning passenger-kms. accordingly.

d) From Ministry of Transportation and Communications.

e) Based on estimate of light van fleet and daily use of 50 kms. for 300 days annually.

f) From PDT.

g) Assuming two occupants per vehicle, this is about the same intensity as U.K. urban automobiles in the 1970's and between U.S. urban and inter-city intensities.

h) Equivalent to U.K. average in 1970's.

i) Below both U.S. and U.K. inter-city bus but above urban bus.

j) Approximately same level as U.S. urban in 1950's.

k) Difficult terrain suggests such a level.

l) High load factors bring intensity down to between U.S. and U.K. levels.

m) Not applicable as sales made to foreign operators. Energy requirements are not directly related to domestic transportation.

VII. GROWTH RATES LIKELY IN THE TRANSPORT SECTOR: 1976-2000

A. Automobile

Three factors militate against rapid growth of automobile passenger-kilometers in the near term (to 1985):

1. The economic difficulties in the country;
2. The mounting urban congestion in Lima; and
3. The poor condition of roads outside Lima.

A 3% growth rate for the period, as forecast by PetroPeru, seems therefore reasonable, as it appears unlikely that all of these difficulties will be surmounted by that time.

After 1985, it is very likely that, if the economic difficulties are successfully resolved, the urban problem will be tackled probably by the construction of a Metro; and inter-city roads will be rehabilitated and provided with regular maintenance and encourage inter-city travel by automobile. A 5% growth for the longer term (1985-2000) is therefore reasonable.

B. Bus

Urban Lima is expanding very rapidly; it is expected that passenger-kilometers in the capital will increase at an average annual rate in excess of 8% although the growth rate is expected to be less over the period 1985-2000. Inter-city bus travel may not expand to such an extent, especially if a coastal rail link north of Lima is constructed. On the other hand, roads will be built in areas presently served only by aircraft or, precariously, by road and some passenger traffic will be generated on these essentially new links.

C. Truck (Freight)

For the period 1976-1986, the PDT estimates an annual growth rate of 5.3% for road freight. Our estimate of 3% for the period 1976-1985 reflects a rather sluggish industrial growth over the next few years but picking up after 1985 to 6.5% per year.

D. Truck (Non-Freight)

Also related to industrial growth with similar growth rates to those for freight trucking.

E. Rail (Freight)

The growth rate projected for rail freight (4.0%) approximates that calculated in the PDT (3.64%).

F. Rail (Passenger)

A slow initial growth is forecast but with the construction of new rail links and improvement in the economic position of the country, inter-city passenger travel by rail should grow faster post-1985.

G. Air

Construction of new airfields and improvements in facilities should aid a healthy expansion of domestic air travel. The projections of 4.2% growth per year, made by PetroPeru are accepted. These also include sales of domestic aviation fuels to foreign carriers.

H. Aviation

The PDT forecasts an annual growth of 9.7% in the cabotage trade of petroleum and products and minerals. Fertilizers and some general cargo may move if efficient cargo-handling systems can be provided.

Our 6% average annual growth rate takes into account some bunker sales to foreign ships. This is the growth for bunker sales forecast by PetroPeru.

The growth rates used to project 1985 and 2000 transport activity levels are shown in Table 20, and the projected activity levels are shown in Table 21.

TABLE 20

ESTIMATED GROWTH RATES OF TRANSPORTATION ACTIVITY LEVEL BY MODE BETWEEN 1976 AND 2000

Mode	Average Annual Growth Rate (%) 1976-1985	1985-2000
Automobile	3.0	5.0
Motorcycle	3.0	5.0
Bus	7.1	5.7
Truck (Freight)	3.0	6.5
Truck (Nonfreight)	3.0	6.5
Rail (Freight)	4.0	4.0
Rail (Passenger	3.0	5.0
Air	4.2	4.2
Ship	6.0	6.0

TABLE 21

TRANSPORTATION ACTIVITY LEVEL PROJECTIONS 1976-2000

Mode	Activity Unit	1976	1985	2000
Automobile	Vehicle - KM	3.25	4.24	8.81
Motorcycle	Vehicle - KM	0.52	0.68	1.41
Bus	Passenger - KM	14.97	27.73	63.98
Truck (Freight)	Ton - KM	5.86	7.65	19.67
Truck (Nonfreight)	Vehicle - KM	0.94	1.23	3.16
Rail (Freight)	Ton - KM	1.03	1.47	2.65
Rail (Passenger)	Passenger - KM	0.53	0.69	1.43
Air	Passenger - KM	1.36	1.97	3.19
Ship	Ton-KM	4.71	7.96	19.08

VIII. TRANSPORT OPTIONS

In planning transportation systems, one is generally faced with a series of options. These may be options between different types of infrastructure or vehicles in one mode or between modes. The primary transport problems that need to be solved in the Peruvian situation are:

1. Urban traffic in Lima;
2. Maintaining the existing infrastructure and vehicles;
3. Forging links with the Eastern part of the country;
4. Expanding the existing inter-city infrastructure to accommodate increasing traffic; and
5. Acquisition of suitable vehicles to handle increases in traffic.

A. Urban Traffic

The Metro-Lima study, finished in late 1973, recommended the establishment of a metro system totaling 60 kilometers by 1992. It has been suggested that a monorail system would be a preferable solution to Lima's urban traffic problem. Such a system, however, would not have the capacity necessary to handle the anticipated passenger traffic. A rationalization program was recommended to solve the confused situation in present surface transport. To date, little has been accomplished on either task. Funds have not been forthcoming for the metro system and great difficulties have been encountered in organizing the numerous bus and minibus operators.

Energy intensity rates per passenger-kilometer for a metro system, which would run with relatively low load factors in off-peak periods, could be higher than for a bus system, as has been the case in the experience of, for example, London where buses have an intensity of $0.8 \text{ J} \times 10^6$ per passenger-kilometer as opposed to $1.6 \text{ J} \times 10^6$ for the underground. In using such analogies, however, it must be remembered that the London underground receives electricity from thermal power stations and that the peak distribution of passenger traffic is different from that of Lima. A detailed analysis may prove the metro less power-intensive per passenger-kilometer than a surface bus system for Lima. The deteriorating situation in surface transport in Lima with increasing congestion could bring bus intensities up significantly above current levels. The use of new or different technologies, such as trolley buses and electrically-driven buses (being considered by MOTC) would allow reduction of dependence on petroleum fuels for urban surface transport.

B. Maintenance of Existing Infrastructure

As mentioned previously in this paper, the road system of Peru is in a state of disrepair over a great part of its length. Significant reductions in fuel consumption can be made by improving road surfaces to allow vehicles to travel at optimal speed. Some of the main inter-city roads are too narrow to allow free flow of traffic; difficulty is experienced in sections with long stretches of inclines, as faster-moving vehicles frequently are unable to overtake slow vehicles. Without conducting surveys designed to relate road conditions in Peru to fuel consumption, it is not possible to quantify likely savings, but a saving of 5% in fuel consumption by putting roads in first-class condition, including widening to accommodate modern traffic requirements, would probably be a conservative estimate on intercity roads.

C. Linking the Eastern Region to the Rest of Peru

With a rapidly-expanding population taxing the resources of the Sierra and coastal regions of the country, it is likely that there will be a movement of people to the Eastern Region, many areas of which open up good prospects for substantial agricultural projects. At the present time, communications between the Eastern Region and the rest of the country are confined to air links and some river traffic in the Amazon system.

In the PDT, a long-term basic transport network is drawn up (Map 2) which, when compared to the actual situation (Map 1), indicates the extent to which road and rail is expected to link such Eastern centers as Yurimaguas, Pucallpa and Atalaya directly with urban areas in the West of the country.

In addition to the planned road and rail links, air services will be improved and better facilities provided for river traffic. In spite of these ambitious schemes, there will still be a need to provide links to settlements that might not justify the building of a road or airport. One solution to this problem, suggested by the Director of the Division concerned with research and development at MOTC in Lima, is to use blimps or airships which require relatively little infrastructure, though a sophisticated docking system, and are extremely efficient users of energy. It was suggested to us that a pilot project using a blimp of about three tons cargo-carrying capacity would demonstrate the utility of this nonconventional mode of transport and result in full-scale cargo services in the future.

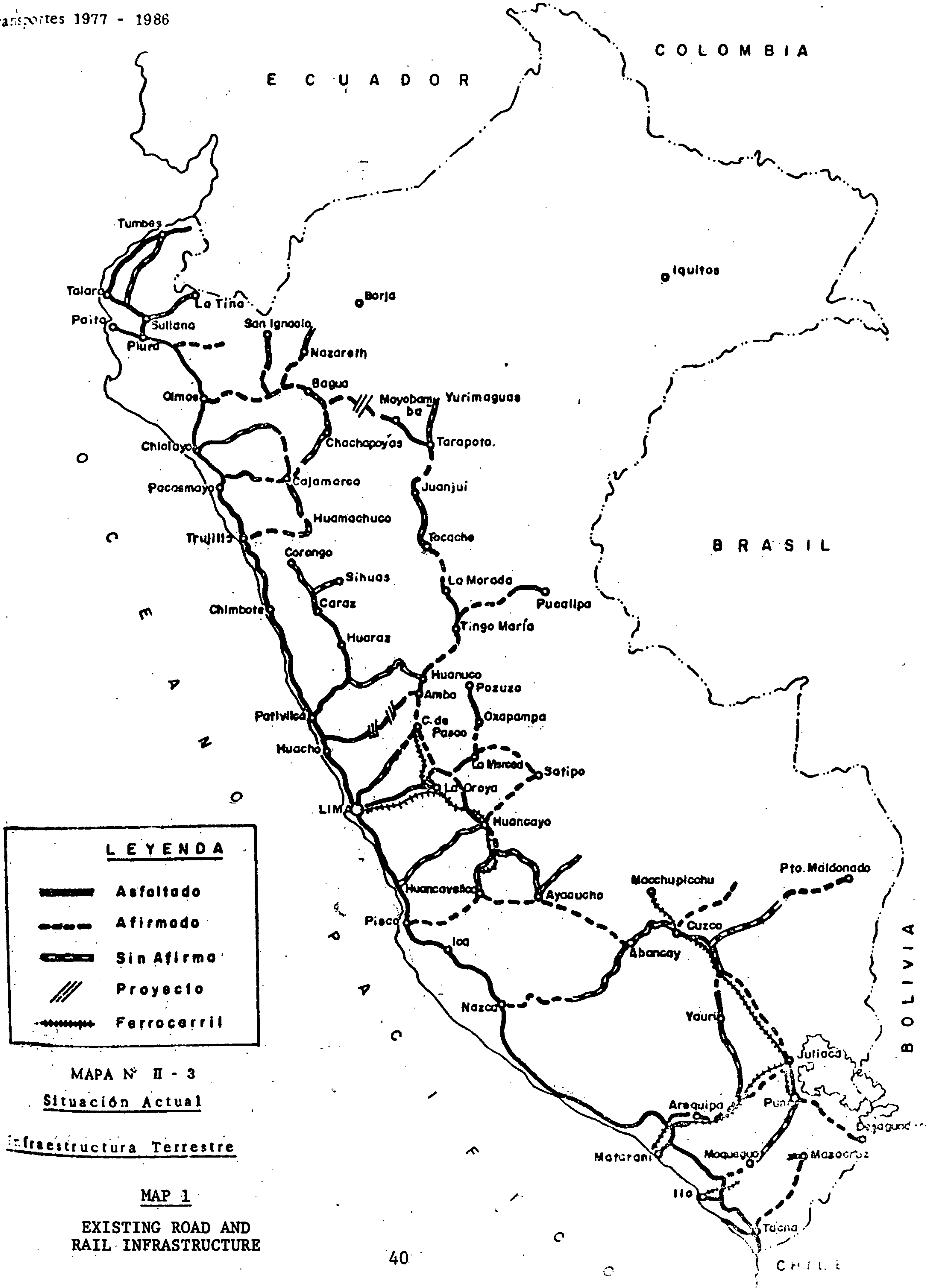
D. Expanding and Improving the Existing Inter-City Infrastructure

Congestion will be experienced on the North-South Panamerican Highway sometime in the 1980's and a decision will have to be made of one or several of the following options:

1. Widen the present highway;
2. Construct a new parallel highway;
3. Construct a rail link parallel to the present highway;
4. Expand cabotage; and/or
5. Expand air services.

Plan Director de

Transportes 1977 - 1986



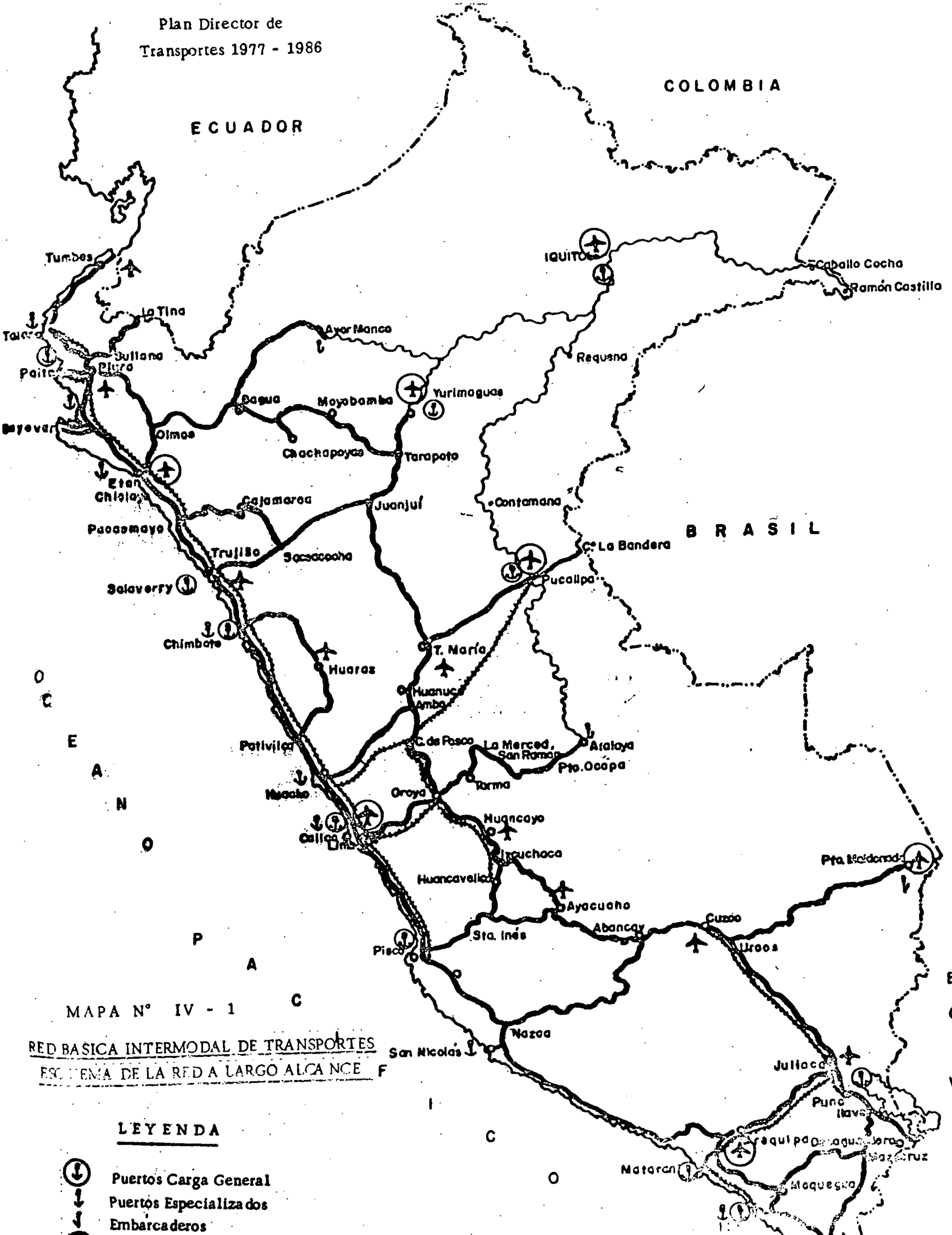
MAPA N° II - 3

Situación Actual

Infraestructura Terrestre

MAP 1

EXISTING ROAD AND RAIL INFRASTRUCTURE



MAP 2

LONG-TERM PLANNED TRANSPORT NETWORK

There is an optimal mode of transport for each commodity depending on the characteristics of the commodity and the efficiency of the mode. Changes in input prices can effect this; for example, an increase in the price of energy for an energy-intensive mode will reduce its competitive position vis-à-vis a less energy-intensive mode.

The construction of the rail line which could carry inter-city passengers, general cargo and bulk freight, in competition with cabotage for bulk freight, road for general cargo, air for long-distance high-speed passenger traffic and road for shorter-distance passenger traffic, is being seriously considered on the route Lima-Chimbote with possible extension to Talara. A prefeasibility study of the Lima-Chimbote link, carried out in MOTC, apparently presents a strong case for such a link.

In constructing such a line it would be advantageous to utilize hydro-electric potential and provide an electrified track. In terms of energy-intensity, it is not at all clear that electric inter-city trains are more efficient than diesel. British experience with relatively high-speed passenger services suggest that the average intensity for diesel locomotive-hauled trains is about 0.9×10^6 joules per passenger-kilometer, and for electric locomotive-hauled trains, 1.0×10^6 joules per passenger-kilometer. Other improvements that have energy implications are electrification of the Central and Southern Railway networks.

E. Acquisition of Suitable Vehicles

The PDT has specified desired vehicle types for all modes of transport. Rail locomotives are to be diesel electric, trucks and buses to be predominantly diesel. It is also desired that new acquisitions be of a limited amount of types. To some degree, options exist; for example, in the case of electrification of rail links, diesel-electric locomotives would be replaced by electric-traction units.

Quantification of options available in practically all cases depends on significantly more detailed knowledge of demand data. The data base is extremely weak in the transport sector--a fact acknowledged by MOTC, and currently being rectified with the help of an aid program sponsored by the Canadian Government. Furthermore, Peruvian experience in transportation is still inadequately documented. Such things as vehicle fuel consumption over different road conditions in the country or average load factors of vehicles are still only rough approximations.

The Transport Ministry Plan (PDT) was a first step to consistently document and really think about the transport sector; in many ways, it was a learning process for the transport planners in the Ministry. Many shortcomings of knowledge of the demand for transport and of the transport sector, itself, have been revealed in compiling this document. The major issues have, however, been discussed and planners in the Ministry are in a better position to proceed more in depth to plan solutions to problems in the transport sector.

APPENDIX 1

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APPENDIX 2

INTERVIEWS IN LIMA WITH PEOPLE IN OR KNOWLEDGEABLE ABOUT PERUVIAN TRANSPORT SECTOR VISIT OF AUGUST 7-18, 1978

1. Edilberto Alarcón, Engineer, USAID.

2. S.C. Cajja Maguiña, Director, Research & Planning Office, Ministry of Transportation.

3. Humberto Moreles, Project Engineer, Inter-American Development Bank.

4. Walter Orjeda, Economist, National Planning Institute.

5. Ricardo Gandolfo, Executive Director, Mass Rapid Transport Project, Ministry of Transportation.

6. Col. Guillermo Fernández Dáuila, Director of Planning, Railroads, Ministry of Transportation.

7. Alejandro Quadra, Director, Road Maintenance Division, Ministry of Transportation.

8. Manuel Luna, Chief, Statistical Office, Ministry of Transportation.

9. A.W. Gemmell and D. Napier, Canadian Transport Commission Assigned to Statistical Office, Ministry of Transportation.

10. Cesar A. Sandoval, Planning Division, PetroPeru.

11. Sara Baella, Economist, Planning Division, Ministry of Transportation.

ANNEX - 4

COAL UTILIZATION

BY

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DEPARTMENT OF ENERGY

U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

NOVEMBER, 1978

COAL UTILIZATION

By Zane E. Murphy

INTRODUCTION

This section discusses the potential for expanded utilization of coal from indigenous sources in Peru. At present, none of Peru's coal resources are being developed nor to the best knowledge are there any firm plans by the Government of Peru or private enterprise to undertake such action. Discussions between the U.S. Energy Team and officials of the Government of Peru's Ministry of Energy and Mines revealed that a Polish-Swiss team has completed a study of the Alto Chicama coalfield to verify the potential coal reserves for a proposed 480 Megawatt (MW) thermal electric power plant. In addition, SIDERBRAS and SIDERPERU are studying the Oyon coalfield to determine its potential as a blend coal to produce coke for the blast furnaces at the Chimbote Steel Plant. No further evidence of planned utilization of coal was found. The general conclusion drawn is that the U.S.-Peru Energy Team would investigate further other options which may have potential.

According to official statistics, the last year that coal was mined in Peru was in 1973, when 12,000 tons of Anthracite was produced in La Libertad Department. Unofficial sources reportedly cite a production of approximately 30,000 tons for this mine that year. In 1971, Cerro de Pasco (Centramin Peru) closed its Goyllarisquizge Mine which had been in operation since 1908. Reportedly between 30,000 to 47,000 tons of bituminous coal were produced during the preceding 5-year period. Basically the reason for the decline and cessation of coal production was due to support of subsidized petroleum products and rising costs of mining. These together proved to make Peruvian coal unattractive in the fuel market.

In 1975, SIDERPERU imported 190.000 tons of Metallurgical coke from Japan for use in its steel plant at Chimbote. In addition, approximately 57,000 tons of metallurgical grade bituminous coal were imported from the U.S. for processing into coke for the copper and lead industries. An unofficial estimate of 12,000 tons of domestic production was cited by INCITEMI for that same year. No official records are compiled by the Government of Peru on domestic coal production or domestic consumption by small domestic mines or household use.

While the coal resources of Peru are not large by world standards, they may be sufficient to provide Peruvian coal needs for many decades. Coals, differing in rank and quality, are known to exist in at least 18 areas of Peru. These coals, the areas of deposit, and the general subject of coal resources and the validity of these reported data are discussed in the section dealing with Peru's coal resources.

COAL UTILIZATION OPTIONS:

Possible uses for an expanded output of coal in Peru are outlined below:

1) Directly Burned as a Source of Heat - Use of coal in households is of limited application. Coal used in central heating systems would be more efficient but still of limited application in Peru. Thus this possibility does not have much bearing on the exploitation of Peru's coalfields.

2) For Coal-Fired Power Stations - In a market of high oil prices, coal may become competitive as a fuel for thermal power stations. In locations in Peru where hydroelectric power is not obtainable or easily developed, coal could be used as a furnace fuel. Because of lack of hydro-power, the mining operations in Southern Peru around Cuajone and Toquepala make use of a large thermal power station at Ilo. To meet the energy demands of the new Cajuone copper mine, the Ilo Station's installed capacity was increased from 110 megawatts to 176 megawatts. The majority of the steam boilers use the waste heat of the reverberatory furnaces of the Ilo smelter with only 3 boilers directly fired with fuel oil. There is a possibility of using coal from the Carumas deposit located near Moquegua northeast of Ilo and about 220 kilometers away for the directly - fired boilers of the Ilo power station.

Pulverized coal could possibly be used also to fire the four reverberatory furnaces at Ilo, which use about 1.2 million barrels of fuel per year. This fuel oil was once imported from Colombia, but is supplied presently from domestic oil production.

However, further reserve and analytical studies of the Carumas coal deposits are required. The feasibility of such a fuel conversion at the Ilo station would also have to be studied. Steam power for the desalinization plant at Ilo is supplied from the Ilo power plant.

It is already noted in other sections of the report, that coal from the Alto Chicama deposit is currently under study by KOPEX for the proposed first stage 200 megawatt (MW) thermo electric plant. Plans include growth of this plant capacity to 480 MW.

3) For Making Coke - Peruvian imports of metallurgical coke (mostly from Japan) are currently estimated at from 150,000 to 190.000 tons per year. SIDERPERU plans to further expand steel capacity to 1.4 million tons by 1980 and 2.3 million tons by 1989, which would require additional inputs of coke.

Coal with high caking tendency and low volatile matter content as well as low phosphorous and sulfur content is required to make satisfactory coke. Blends of coals often prove to be acceptable. The potential of Peruvian coal for coking purposes would be a leading consideration in any program to expand production in Peru's coalfields, together with electrical power generation. Relative to coking qualities, the Jatunhuasi coal appears to offer better possibilities than the coal from Oyon. Available test data have shown that the Jatunhuasi coal is a true bituminous coal which could be blended with imported coal to make a satisfactory blast furnace coke.

A smaller quantity of coke is also used for the smelting of lead at CENTROMIN's metallurgical complex at La Oroya, east of Lima. As noted previously, Peru used 61,800 metric tons of coal in its mining operations in 1974. More current figures are not available. It should be noted that the Jatunhuasi coal field with coal of coking quality is closer to the La Oroya smelter than to the steel mill in Chimbote, north of Lima.

4) For Conversion to Clean Synthetic Gas or Oil - It is possible that some of the Peruvian coal not suitable for coking could be used for this purpose at a later date.

5) For Export - If and when the quantity and quality of coal available for production has been determined, the possibility of resuming exports of Peru's surplus coal should be investigated. Brazil imported 2.9 million tons of metallurgical coal in 1976 and may be a possible export market in the future.

A discussion of the application of Peruvian coals is academic in nature until such time as these respective coal deposits are further identified as to: first, their extent and recoverability in a technical mining sense; second, a more thorough knowledge of their chemical and physical characteristics which would allow an assessment of their utility; and thirdly, a study of their economic applicability to consuming sectors of the Peruvian economy.

Faced with insufficient data and information relative to utilization we can cover the above listed requisites, however, and point out what data are lacking to allow a reliable assessment for the three items under discussion.

1. Coal Recovery

Coal recovery in this discussion recognizes not only the application of commercialized mining technology, but also the transportation of the mined product from the mine to consumer.

Mining Problems:

The mining of coal in Peru confronts us with a number of problem elements; adverse geology, lack of infrastructure in potential areas, need to rehabilitate abandoned mines, and lack of equipment. A study needs to be made of the financial investment required to surmount the problems prevailing in the various coalfields. Most deposits require underground mining methods. Surface mining techniques may be applicable in limited places.

Geology: The coal deposits in Peru are located along the axis of the Andean Mountain range. In some coal areas like Alto Chicama and Oyon tectonic activity with extended folds, overthrusts, and faults has been intense and the original flat-lying coal beds are quite deformed. The dip of the beds at Oyon run 40 to 50 degrees and at Alto Chicama from 60 to 80 degrees. The tectonic activity at Jatunhuasi was not as intense. The Oyon and Alto Chicama coal beds also have igneous instrusions from intense magmatic activity; whereas in the central part of Jatunjuasi, the igneous intrusions are practically nonexistent. Coal beds are thin in some areas making the use of mining machinery difficult.

Infrastructure: Most of the coal deposits are located in remote areas without the support services required for mining such as water supply, power, and transportation facilities. In abandoned coal areas such as Santa, once natural roads are in disrepair and subjected to land slides. A railroad line at Santa needs to be rehabilitated. In the case of the Jatunjuasi coal area, which offers the best possibility of supplying coal of coking quality or for blending, there is access to a railway which reaches the coalfield and which connects with Peru's central railway. The main disadvantage of the Jatunhuasi coalfield is the thinness (between 2 and 3 feet) of the coal seams. Mine output would therefore be more limited in this area.

Equipment: For expanded coal production, Peru would have to import a variety of mining equipment. In certain abandoned coal mines, locomotives and mine cars exist in relatively good condition. Some old mines like Mina Centenario in the Santa coalfield had in 1975 a well-stocked mine store with a variety of equipment such as pumps, electric motors, survey equipment, carbide lamps, etc. Other abandoned mines, however, were stripped of equipment. Some mine drifts were found in excellent condition.

Labor: Peru has a long-established mining tradition with a reservoir of experienced miners which could probably be drawn upon for any expanded or new coal production.

Relative to coal developments, in April 1976, Electricidad del Peru (ELECTROPERU) and Minero Peru signed a contract with a joint venture of Kopex of Poland and Universal Engineering of Switzerland to carry out a technical-economic study, estimated to cost $1.8 million, of the Alto Chicama coal mine and energy complex. The Alto Chicama deposit lies 480 kilometers north of Lima and east of Trujillo.

The project in the first stage includes construction of a thermo-electric plant to generate 200 megawatts of power and a mine complex to produce 2,000 tons of coal per day. In the second stage 480 megawatts will be produced requiring 4,200 tons per day of coal output. The project is expected to be operational by 1982. The plant would supply energy for the proposed Michiquillay copper project and the proposed fertilizer-petrochemical complex at Bayovar. Measured coal resources/reserves at Alto Chicama are estimated at 50 million metric tons of anthracite. Inferred Alto Chicama resources/reserves are 250 million tons. SIDERPERU is studying the coal in the Oyon deposit for possible use in production of metallurgical coke.

Based on geologic studies and limited mining data, Peru's total coal resources/reserves have been estimated at 1.06 billion tons classed as follows: 830 million tons anthracite, 130 million tons bituminous and 100 million tons lignite. Of this total 130 million are considered to have potential for coke-making quality. The validity of these estimates is questionable, due to the small amount of resource investigation that has taken place previously.

TABLE 1 Classification of Coals by Rank[a]

Class	Group	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis): Equal or Greater Than	Fixed Carbon Limits, percent (Dry, Mineral-Matter-Free Basis): Less Than	Volatile Matter Limits, percent (Dry, Mineral-Matter-Free Basis): Greater Than	Volatile Matter Limits, percent (Dry, Mineral-Matter-Free Basis): Equal or Less Than	Calorific Value Limits, Btu per pound (Moist,[b] Mineral-Matter-Free Basis): Equal or Greater Than	Calorific Value Limits, Btu per pound (Moist,[b] Mineral-Matter-Free Basis): Less Than	Agglomerating Character
I. Anthracitic	1. Meta-anthracite	98	...	...	2	...	...	nonagglomerating
	2. Anthracite	92	98	2	8	...	...	
	3. Semianthracite[c]	86	92	8	14	...	...	
II. Bituminous	1. Low volatile bituminous coal	78	86	14	22	...	...	Commonly agglomerating[e]
	2. Medium volatile bituminous coal	69	78	22	31	...	...	
	3. High volatile *A* bituminous coal	...	69	31	...	14 000[d]	...	
	4. High volatile *B* bituminous coal	...	...	...	...	13 000[d]	14 000	
	5. High volatile *C* bituminous coal	...	...	...	...	11 500	13 000	
						10 500	11 500	agglomerating
III. Subbituminous	1. Subbituminous *A* coal	...	...	...	...	10 500	11 500	nonagglomerating
	2. Subbituminous *B* coal	...	...	...	...	9 500	10 500	
	3. Subbituminous *C* coal	...	...	...	...	8 300	9 500	
IV. Lignitic	1. Lignite *A*	...	...	...	...	6 300	8 300	
	2. Lignite *B*	...	...	...	...	...	6 300	

[a] This classification does not include a few coals, principally nonbanded varieties, which have unusual physical and chemical properties and which come within the limits of fixed carbon or calorific value of the high-volatile bituminous and subbituminous ranks. All of these coals either contain less than 48 percent dry, mineral-matter-free fixed carbon or have more than 15,500 moist, mineral-matter-free British thermal units per pound.

[b] Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

[c] If agglomerating, classify in low-volatile group of the bituminous class.

[d] Coals having 69 percent or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of calorific value.

[e] It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and there are notable exceptions in high volatile *C* bituminous group.

2. Chemical and Physical Characteristics

Basically, all coals contain common chemical elements and possess relative physical characteristics.

There are three general categories of coal that have commercial value:

1. Anthracite
2. Bituminous Coal
3. Lignite

Each of these categories has subdivisions, but it is not necessary to be that specific about the classification of the coals for this discussion. Table I illustrates the complete classification of coal by rank for information purposes.

Anthracite

This coal is termed "hard coal" and has a fixed carbon content from 86% to 98%. It has a black metallic luster and ignites with difficulty, burns with a short blue flame and is virtually without smoke. Anthracite is not as prevalent nor as universally useful as bituminous coal.

Bituminous Coal

This is the most commercially desirable coal. It has a fixed carbon range of 69% to 86% and has a volatile matter range of 14% to 31%. Its calorific value ranges from 10,500 Btu/lb through 14,000 Btu/lb. It has the broadest industrial application including the source of metallurgical coke.

Lignite

Lignite is intermediate in the stage of coalification between peat and subbituminous coal. It is identified more by its calorific value than its fixed carbon. Heating values range from less than 6,300 Btu/lb through 8,300 Btu/lb. It occurs with broad ranges of sulfur and a high volatile content.

Since man's first domestic and industrial utilization of coal, recognition of differences between the various coal deposits has been apparent. Coal deposits throughout the World have been categorized as to their applicability, to meet, first, broad market demands, and then more specifically to permit selectivity of application within a definite market. For example, all coals contain the basic combustion ingredients carbon and hydrogen, and will combust to release energy in the form of heat. However, some coals combust more readily and with less residue left behind and are preferable for those reasons. On the other hand, technology evolved a method to refine metals using coke (a carbon and ash residue formed when selected coals are heated in an absence of air). Other uses of coal have been found such as use of coal as a filter medium in municipal waste treatment plants. These are mentioned to draw attention to the selectivity that is exercised in choosing specific coals for specific applications. As the worldwide coal technology became better defined, so too, did the utilization of the various ranks and quality of coal. At present, coals are referred to as steam coals or metallurgical or coking coals utilized to produce metallurgical coke for use in steel making, metal smelting, or in foundries.

Being aware of highly competitive situations that exist in the world as a community today, coals are developed only after careful overall economic considerations are studied.

COAL CHARACTERISTICS

Further comment on end use utilization requirements of specific coals is in order here. Two basic assumptions are made. They are that virtually all Peruvian coals developed will either be for (1) metallurgical coke production or for (2) electrical energy production or industrial plants. Little if any production is projected for domestic heating at present.

In case (1) and (2) above, further discussion follows of what coal specifications must be met to qualify a given coal. For consideration in the production of metallurgical coke for steel making, case (1), the state of the art in blending coal has reached an apex. Virtually, all metallurgical cokes are produced from a blend of two or more coals.

It can be stated with a high degree of validity that specific coals in metallurgical use are selected for their demonstrated ability to produce premium cokes. Further, it should be recognized that no standard definition exits as to what precisely defines a coking coal as differing from a steam coal. Simply stated, a coking coal is any coal that produces a coke residue. At times the same coal that is mined and shipped to the coke plant also is shipped to the thermal generating plant to generate steam in a boiler. This point is brought out to indicate the degree of confusion in coal terminology when reference is made to end utilization patterns.

Coke making, and good coal combustion in a boiler are more accurately described as arts, not as true sciences. The reason for this statement is that sciences are defined and behave in a precise and predictable manner. This is not always the case in the behavior patterns for coals used to make coke or in the combustion process.

It often has been stated that the coke produced is the important substance, not the constitution of the coals used to produce that coke. While that may sound like a paradox, it should not be considered as being so.

Metallurgical Coking Coal

Because metallurgical coke is so vital to heavy industry, it is worth some additional comment with regard to coal utilization. The process of making coke is carbonization of coal.

When coal is processed to produce coke, it is carbonized or heated in the absence of air to break down its constituents. The resulting products are coke, liquids and gas. Coal chemicals recovered in the process include tar from which are produced crude chemicals and materials for creosoting, road paving, roofing, and waterproofing, light oils, mostly benzene and its homologues used for motor fuels and chemical synthesis; ammonia, usually as ammonium sulfate, used mostly for fertilizer; to a lesser extent tar acids (phenol), tar bases (pyridine), and various other chemicals.

High-temperature carbonization is carried on in ovens or retorts with innerwall temperatures of from 1850 to 2100°F. A typical yield from 2,000 lbs of high-grade dry coal of 30-31% volatile matter when carbonized in a modern oven is: coke, 1,440 lbs; gas, 348 lbs (11,200 cu ft); tar, 96 lbs (10 gal); water, 87 lbs; light oil, 24 lib (3.3 gal); and ammonia, 4.9 lbs.

Chemical and Physical Characteristics

Most high-rank bituminous coals can be used to make coke and gas. Those well adapted to that purpose are not numerous. The coal must form a strong coherent coke and must not swell excessively during coking to damage the oven walls. Coal for the best metallurgical coke should preferably have a low ash and sulfur content (ash below 7.5 and sulfur below 1.0% is good). Some coking coals now exceed these figures. The coke produced should be strong and blocky. Coal for the production of gas should have a high volatile-matter content (30-40%). In general, the higher the volatile-matter content, the greater the yield of gas and coal chemicals; the lower the volatile-matter content, the stronger the coke.

The coking quality in bituminous coals is limited also by the oxygen content. Coals of over 10.0% oxygen content (on the dry, ash-free coal basis) generally do not coke appreciably. A high-oxygen content (7-10%) usually denotes poor coke.

It is common practice in coal-chemical-recovery coking to mix two or more coals to make a better grade of coke or to avoid excessive expansion in the oven. One coal is usually of high (31-40%) volatile-content and the other of low (15-22%). A wide selection of medium-volatile (22-31%) coals are used. The low-volatile coal in the mix is generally in the range of 15-25%, with as much as 50% used in coal mixtures for producing foundry coke. High-volatile coals tend to shrink on coking while low-volatile coals tend to expand. Preliminary examination of the plastic properties, when heated, is of value in choosing the best types for blending; the high-volatile coals tending to be more fluid, and the low-volatiles less so.

Coals that are considered in coke making are selected based on several chemical considerations such as moisture, ash, phosphorus, oxygen, volatile matter, and sulfur contents. In addition, they must display physical attributes which upon heating produce a cellular residue with a satisfactory free-swelling index number. The blends that are made recognize these respective limits of the coal and the blending of the coal produces the desired coke product. While it is rather meaningless to generalize as to coal constitution some idea as to ranges of these values for coals used in blends are as follows:

Constituent	(wt. Percent)
Moisture	4.0 - 6.0
Ash	6.0 - 12.0
Sulfur	0.6 - 1.5
Volatile Matter	16.0 - 35.0
Phosphorus	0 - 0.03
Oxygen	5.0 - 10.0
Free Swelling Index (FSI)	5.0 - 9.5

An area of potential for Peru's indigenous coal resources in conjunction with a developing iron and steel industry is form coke. This is a material which can be produced from virtually any type of coal, coking or non-coking, which, according to reliable reports, can be used for iron reduction in blast furnaces in place of conventional coal coke. At the present time, there is little interest in form coke in the United States because most of the U.S. steel industry consists of integrated coke oven-blast furnace operations that operate in an effective economical environment. Also, the U.S. steel industry has large supplies of coking coals. Form coke, however, could be a material attractive for use in new steel plants because such plants would not have to be concerned with problems such as retrofit. This would apply particularly to a developing steel industry in Peru.

Presently, there are six form coke processes that have potential for commercial development at this time. These processes are:

1. Lurgi - BBF (West Germany)
2. Ancitt (Netherlands)
3. FMC (United States)
4. DKS (Japan)
5. HBNPC (France)
6. Sapozhnikov (U.S.S.R.)

To date, none of the above processes has been tested on a sufficiently large scale that would ensure satisfactory use of the product in large blast furnaces. Many blast furnace trial runs have been conducted, however, and the results of these tests have shown that form coke can be used in some blast furnaces as a full or partial replacement of their requirement for conventional coke.

In the discussion of case (2), coals for electrical energy production or industrial plants, it can be stated that virtually any coal can be combusted in a boiler if it is properly designed for that particular coal. This fact is both good and bad because once the boiler design is selected, it can and often does limit the use of other coals that may become available at a later date.

Internal design and the number of boiler tubes and boiler configuration as well as calculation of required heating tube surface in the radiation and convection sections of a conventional steam boiler are dependent largely on the specification of the fuel (coal, petroleum, or natural gas). Boilers are designed with a knowledge of how well previous designs have functioned within loosely defined limits according to the design engineer's talent. The engineer will design the boiler based on the reactivity of the fuel, flame emissivity, and a host of other factors such as fuel chemical content of moisture, ash, sulfur, chlorine, alkali salts, etc., also the design engineer will pay close attention to tube temperatures to assure that the ash residue does not adhere and cause deposition problems, which will coat the boiler tubes and seriously affect the heat transfer process and can result in boiler failure. All of these factors he must consider within the limits of a specified operational efficiency range for that boiler.

Conventional Combustion

The discussion of the conventional combustion of low quality coals is developed to provide insights on the potential application of this technology in countries currently lacking in sophisticated industrial developments. An overview of some of the technical and economic problems associated with adopting the technology is presented in an effort to evoke solutions to some of these problems and hasten implementation of the technology. This discussion will touch upon most of the practical applications but available time limits the number of these that can be examined in detail. The objective is to define the greatest number of applications appropriate for a given country in order to establish a foundation for more detailed investigations.

Combustion Equipment

Selection of a coal burning system involves the operating characteristics desired, efficiency, investment and type of coal burned. Three basic systems will be considered:

1. Stoker firing (Limited to maximum of 30 MW)
2. Pulverized coal firing
3. Cyclone furnace firing

For steam generating installations of under 100,000 pounds per hour, the stoker is adequate. Some sacrifice in efficiency is given in favor of a wide range of firing capacity. For industrial furnaces pulverized-coal firing is preferable.

The cyclone furnace is better suited to a wider variety of ranks of coal even though the low quality coals can be burned successfully in the two other systems. The choice is a matter of judgment by virtue of the operating characteristics involved. A following section summarizes the primary characteristics of each system for comparison and to assist in selecting the right system for a given requirement.

Generally stokers are not available in sizes over 30 MW and their use diminishes in applications over 200,000 lb per hour of steam generation. It isn't the intention to rule out the possible application of stokers, but only to define general areas of application relative to energy needs.

Auxiliary Equipment

The conventional combustion of low rank coals does not require unique auxiliary equipment to any greater extent that for the furnaces. Combustion air blowers, crushers and pulverizers, conveyors and ash handling equipment are all readily available. Sizing of this equipment to the job requirements is the area of major effort. Certain aspects of the low quality coals require some additional consideration. The high moisture content will require somewhat higher primary air volumes and pressures and cyclone furnaces again increase the pressure needs, over what is required for pulverized coal burners, 2 to 10 inches of water versus 20 to 40 inches of water for cyclone furnaces.

Precipitators or ash cyclones will also be required depending on the type and size of furnaces selected. Heat recovery equipment is primarily used in the system to recover waste heat and preheat combustion air. The preheated air is a requirement for more effective handling of the high moisture content coals for use in pulverized coal furnaces. The drying effect lessens sticking of the coal in the pulverizers and improves furnace efficiency. Any new installations should include waste heat recovery equipment for furnaces and boilers. An increase of 100°F in combustion air temperature will increase combustion efficiency by about 2%. Properly operated air preheaters can improve combustion efficiency as much as 15%. The cost of installation is considerably less when furnaces are first being erected than on retrofit of existing equipment.

There are limitations on the maximum air temperature through a pulverizer. If the coal moisture content is fairly high, primary air may enter at 650°F. However, the air must exit at 120°F to 140°F when burning lignite because of the danger of combustion in the crusher.

Maximum temperatures for stokers are less restricted and usually only limited by the materials of construction of the blowers and air ducts. Ash handling for stokers is usually done by dropping them into a hopper under the end of the grates or sides if they are stationary. From here they may be removed manually or enter a pneumatic or mechanical conveyor system. Disposal of coal ash can be a problem particularly with low rank coals because of the greater volumes of coal required for a given amount of heat.

On larger installations the energy requirements for the auxiliary equipment is considerable. Fans, conveyors, crushers, stokers and pumps are best suited to electrical power inputs. If electrical power is not available; on site generation might be considered. If steam is available, it can be used to generate electricity or in some cases used to drive a turbine as a direct application to these auxiliaries. Small turbines are available to match the power requirements of most of the auxiliary equipment. Gas turbine and reciprocating engines are also alternative power drives to be considered. Steam turbines are especially desirable if low pressure process steam is needed.

Coal Burning Equipment Operating Characteristics*

Pulverized

1. Load range is wide and varies with the number and type of pulverizers.

2. Flyash carry-over in the flue gases is high, and it is finer than the flyash from the spreader stokers. Therefore, although the boiler must be designed to prevent erosion, the allowable flue gas velocity is somewhat higher.

3. Initial cost for pulverized coal equipment is about the same as for spreader stokers at 250,000 lb/hr. It becomes less expensive above these capacities.

4. Pulverized coal equipment can burn a very wide range of coal.

5. Maintenance costs for pulverizers vary considerably with types of coal.

6. Response to load changes is very fast.

7. Coal sizing to a pulverizer is 3/4 in. x 0. Coal segregation is no problem.

8. Repairs and maintenance on pulverizers may be conducted while the boiler is in operation by taking one of several pulverizers out of service at a time.

9. Grindability of the coal is important to maintain proper pulverizer mill capacity.

Cyclone

1. Load range similar to pulverized coal but simpler to regulate.

2. Less flyash carry-over in flue gas than pulverized coal or stokers.

3. Lower fuel preparation cost because coal only has to be crushed not pulverized--95% through a 4 mesh screen versus 70% through 200 mesh screen.

4. Developed primarily for low rank fuels but burns all grades equally well.

5. Fast response to load changes.

6. Less maintenance on crushers than pulverizers.

7. Heat release rates are in the 450,000 to 800,000 Btu/cu/ft-hr range with gas temperatures in excess of 3,000°F.

8. Reduction in furnace size over pulverized coal.

9. Ash-fusion temperatures are critical, fusion temperature should not exceed 2600°F.

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*Modified from Evaluation of Low-Sulfur Western Coal Characteristics, Utilization, and Combustion Experience, EPA-650/2-75-046, May 1975

Chain and Traveling Grate Stoker

1. Wide load range from banked fire to maximum capacity.

2. Low flyash carry-over in the flue gases.

3. Initial cost is more than for an underfeed stoker.

4. Ash softening temperature should be reasonably high, about 2200°F or higher.

5. Maintenance costs are generally low.

6. Response to load changes is about medium, faster than the underfed but slower than the spreader.

7. Coal sizing should be 1 in. x 0 with approximately 20% to 50% through a 1/4 in. screen.

8. Coal should have a minimum ash content of 6% on a dry basis to protect the grates from overheating.

9. Sensitive to changes in coal sizing and distribution.

10. Offered for a maximum continuous burning rate of 425,000 Btu/sq ft-hr with high moisture (20%), high ash (20%) bituminous coals, and 500,000 Btu/sq ft-hr with lower moisture (10%), lower ash (8-12%) bituminous coal. Furnace heat release should be a maximum of 30,000 Btu/cu ft for water-cooled furnaces.

11. Large (above 70,000 lb/hr) front arch, chain grate stokers should have a maximum heat release of about 7 MKB/ft (MKB - million Btu) of stoker width, depending upon the volatile matter and heating value.

12. Strongly coking coals (more than an FSI of #6) are not suitable for conventional chain or traveling grate stokers.

Underfeed Stoker

1. A wide load range banked fire to maximum capacity.

2. Low flyash carry-over with the flue gases, provided the stoker is not overloaded.

3. Initial cost is low compared to other stokers.

4. Ash softening temperature should be 2500°F or above for best operation. Coals with ash softening temperature of 2200°F may be utilized; however, the heat release rate per square foot of grate area must be reduced about 20%

5. In general, maintenance costs are higher than for other stokers.

6. Response to load changes is rather slow, because of the relatively large fuel bed.

7. Coal sizing should be 1-1/4 in. x 0, nut and slack, with not more than 50% through 1/4 in. screen to obtain proper distribution on the grate.

8. The free swelling index should be below six to maintain a proper fuel distribution on the grates in the furnace and to keep maintenance to a minimum.

9. Grate heat-release rate should be no more than 425,000 Btu/sq ft and a maximum furnace heat release rate of 35,000 Btu/cu ft for water-cooled furnaces.

Spreader Stoker

1. Turn down or load range is generally from 1/5 load to maximum capacity. With additional equipment, minimum load can be decreased to about 1/8 of maximum load.

2. Since about 20% of the coal burns in suspension, the flyash carry-over is high. A dust collector is always required. A precipitator may be required depending upon the air emission regulations.

3. To obtain the best reasonable efficiency, the flyash collected in the boiler hoppers can be reinjected onto the stoker grate.

4. Initial cost of a dumping grate spreader stoker is the lowest, with the pulsating or oscillating grate next, and the traveling grate the highest.

5. The spreader will burn with little difficulty a wide variety of coals of different fusion temperatures and different coking indices.

6. In general, maintenance costs are approximately the same as for a chain grate.

7. The spreader stoker has a very fast response to load swings.

8. Coal sizing should be 3/4 in. x, with no more than 50% through a 1/4 in. mesh. The pulsating or oscillating grates should be fired with coal having an ash softening temperature of above 2200°F to ensure proper coal and ash flow over the grates.

9. Spreaders are designed for burning rates from 450,000 Btu/sq ft-hr for dumping grates to 600,000 Btu/sq ft-hr for pulsating or oscillating grates to 750,000 Btu/sq ft-hr for traveling grates. Furnace heat release should be a maximum of 30,000 Btu/cu ft.

10. On large spreaders (above 70,000 lb/hr steam capacity) the heat release per foot of a stoker width must also be considered, and will vary from about 8 MKB/ft-hr to 13 MKB/ft-hr depending upon the amount and method of flyash reinjection.

11. Some mention should be made of the two types of reinjection generally used: pneumatic and gravity types. The gravity type is much preferred for the higher steam capacities, (above 70,000 lb/hr) if equipment arrangement and building space is sufficient. As the name implies, the flyash flows by gravity from the boiler hopper and is deposited on the stoker grates. The stoker should be lengthened to accommodate this gravity return.

<u>Vibrating Grate Stoker</u>

1. A wide load range-form banked fire to maximum capacity.

2. Low flyash carry-over unless the unit is overloaded.

3. A dust collector may be required, depending upon local conditions.

4. Sizing and distribution of coal is important.

5. Coking coals have been burned on this stoker.

6. Water-cooled grates tend to reduce grate maintenance when properly designed.

7. Burning rate is usually about 400,000 Btu/sq ft-hr with a furnace heat release of 30,000 Btu/cu ft.

Coal Preparation for Conventional Combustion

The initial steps in preparing coal for use in the conventional manner include receiving, storage for a month's supply and crushing. The size of coal required for the various conventional burning systems has been discussed in the preceding paragraphs. No pretreatment is required.

<u>Atmospheric Fluidized Bed Combustion (AFBC)</u>

Atmospheric fluidized bed combustion is an advanced combustion technique in which crushed coal burns in the presence of crushed limestone while held in suspension by upward-flowing combustion air. The technique has two advantages. The first is that rapid heat transfer and high heat-release rates at reduced temperature can be obtained, so that boiler tubes can be imbedded in the combustion zone, resulting in smaller boilers. The second is that the limestone acts as a sorbent to chemically remove sulfur dioxide directly from the combustion zone. As its name implies, AFBC occurs at near atmospheric furnace pressure.

An AFBC utility power plant is envisioned to consist of four separate modular units, each of which is composed of four fluidized-bed cells, plus one high-temperature carbon burnup cell (CBC), which is required to prevent appreciable loss of coal energy from unburned coal leaving the combustor. Steam from each of the modules is combined to drive a single conventional steam turbine generator. The modular concept, which is required because of bed size limitations, is also expected to provide the station operator with some flexibility in meeting partial load demands and reducing total plant maintenance outages by allowing for the removal of individual modules from service. Stacks, fans, and cooling systems would be equivalent to those in conventional coal combustion systems. The overall heat rate of the AFBC plant would be about 9550 Btu/kWh, equivalent to a thermal efficiency of approximately 36%.

In the case 2, it is reasonable to assume that any boiler selection would be in all probability of the conventional type. This assumption is based on the historic trend that has been witnessed in the application of newly developed technology in general throughout the world. With very rare exceptions, a time lapse of 20 years or more has been traditionally followed in the adaptation of new technology, once that technology has been demonstrated to be commercially available. Therefore, developing technologies, no matter how well advanced they may appear to be at this time, should be viewed with a low priority in boiler selection. This implies that fluidbed combustion-type boilers, although they appear to show promise in other applications throughout the world, especially in the U.S. and the United Kingdom, may have limited value in Peru.

3. Economic Applicability

The discussion of economics of reopening oil mines or development of new coal mines in Peru and installation of coal-fired thermoelectric or industrial plants is undertaken with full knowledge of the paucity of information available.

The development of mine capacity would depend heavily upon the result of coking studies presently underway in Peru. The conclusions of that study at best indicate continued dependence upon higher quality coals to improve the quality of coke produced for the steel industry. The coals which could be produced potentially for the copper and lead industries could be of lesser quality.

Based on this assumption as much as 80,000 tons per year of bituminous coal and an estimated 15,000 tons of anthracite may be potentially made available from indigenous sources to supply the need for coking coals at the Chimbote steel plant at present. Future coal requirements could roughly double by the year 2000 according to the projected steel production level for that year.

The reopening of old mines would require further economic evaluation of the condition of those mines. Presently, the estimated cost of installation of new coal mines in the U.S. ranges from $30 to $45 (US) per ton capacity of the mine. Conceivable costs to produce the coal and mine installation would be lower in Peru due to a captive labor supply. Miners' wages in the U.S. presently average about $70.00 - $75.00 per day.

The copper smelters and lead foundries reportedly in 1977 required approximately 60,000 tons. This coal was imported from the U.S. at a cost of approximately $70.00 (US) per ton. Conceivably as much as 40 to 50 percent of this coal requirement could come from indigenous sources.

Conclusions

The main points that emerge from the preliminary study of coal utilization in Peru can be summarized as follows:

1. Peru undoubtedly has coal resources which could be developed. The existing information and data related to these resources are not sufficient to allow a good evaluation. Quantitative and qualitative information needs to be developed to allow a reasonable assessment.

2. Sizeable capital investments will be needed to establish domestic sources of coal supply and to provide the coal burning facilities, such as thermal power plants.

3. Development of coal and coal utilization, except that specifically destined for industrial use (i.e. coke production for steel plants or for producing steam for industrial use), is in direct competition to the development of hydropower. Vast hydropower resources are available in Peru.

4. Both mining technology and coal utilization technology are sufficient to mine--and use Peruvian coals.

5. A discussion of the utilization of Peruvian coals is academic until such time as these respective coal deposits are further identified and more quantitative and qualitative information is developed.

ANNEX - 5

REPORT ON HYDROPOWER - PERU

BY

PAUL WILLMORE, PLANNING ENGINEER

AND

JOHN H. STEELE, HYDROLOGIST

U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

JULY, 1978

EDITOR'S NOTE

The reader will note some differences between the water resource data presented in the Main Report and this Annex. This is a result of the inaccessability of some areas in Peru, the preparation of estimates and measurements by different organizations at different times, and the difficulties of obtaining accurate data. Notwithstanding these differences, however, the conclusions in the Main Report and the water resources Annexes remain unchanged because the differences are small when compared to the Peruvian total water resource.

4.0 SOLAR THERMAL POWER

4.1 Introduction

There are active R&D programs in solar thermal power technology in the United States, Europe, and Japan. As a result of these programs, several small scale (1-150 kW) units have been installed for irrigation pumping, air conditioning, and power generation applications. These installations include those developed by Sofretes in France, Dornier in Germany, and a number of firms in the United States. All these units have used organic Rankine cycle engines to convert heat provided by solar collectors into mechanical power. Sofretes uses non-tracking flat plate collectors in order to simplify system operation for use by unskilled personnel in remote areas. Most other systems installed to date use parabolic trough collectors in order to generate higher temperatures that lead to higher efficiency operation.

For large scale power generation, the primary focus in both the United States and Europe has been on the central receiver concept. In this system, radiation incident on the multiplicity of individually controlled mirrors (called heliostats) is redirected to a single central receiver placed on a tower located in or adjacent to the mirror field. The heat generated in the receiver can be used to operate conventional steam power plants or, in advanced configurations, Brayton cycle engines. Many of the subsystems required to operate a central receiver power system are in the advanced design and testing stage, and the first demonstration of a total system (10 MW) is scheduled for 1981 in Barstow, California.

There are therefore a number of solar thermal power system options in various stages of development. It is expected that ongoing development and demonstration programs will lead to the commercial availability of systems over a wide power range by the early to mid 1980s.

Solar thermal power systems are comprised of a combination of thermal collectors, reflectors, heat exchangers, and thermal engines which utilize conventional manufacturing techniques in their assembly and are made of common materials of construction (steel, aluminum, glass, concrete). With the exception of aluminum products, these systems could be produced in Peru, providing an additional incentive to consider their widespread use. Systems using aluminum could be redesigned to use steel or some other more available metal.

4.2 Description of System Options

As previously indicated, there are many approaches to solar thermal power being investigated. These include low to medium temperature (100°-300°C) systems which can utilize low levels of solar concentration, and high temperature systems (300°-1000°C) which requires high levels of solar concentration. Several of these system options include;

Low Levels of Solar Concentration (1X-10X):

- Flat plate collector with Rankine cycle engine
- Compound parabolic concentrator (CPC) with Rankine cycle engine
- Flat plate collector using planar reflector with Rankine cycle engine

Medium Levels of Solar Concentration (10X-400X):

- Parabolic trough with Rankine cycle engine
- Linear slat concentrator with Rankine cycle engine
- Linear Fresnel lens with Rankine cycle engine

High Levels of Solar Concentration (400X-1500X):

- Parabolic dish with open Brayton cycle engine
- Parabolic dish with Stirling engine
- Central receiver system with steam turbine
- Central receiver system with open Brayton cycle engine

The economic performance of solar thermal power systems is most influenced by the cost and thermal performance of the solar collector subsystem used to convert solar energy into heat.

Several of these collector subsystems appropriate for thermal power applications are discussed in the following sections.

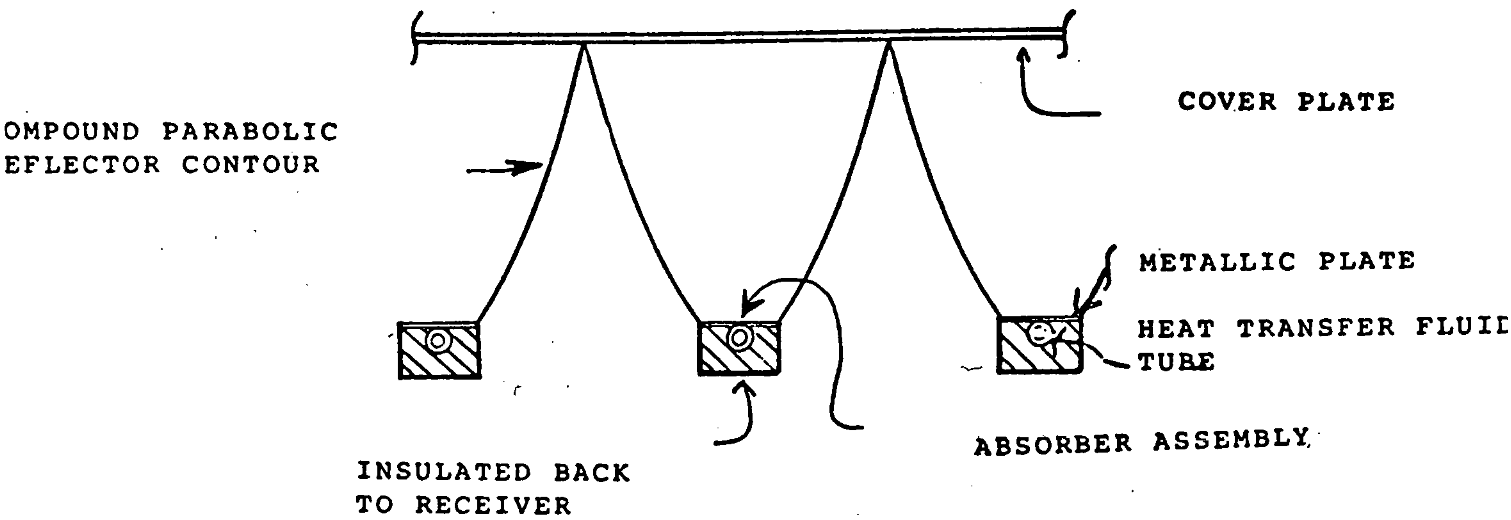
A. Low Level Concentrators

Flat plate collectors of advanced design have been used as heat sources for operating organic Rankine cycle engines at low temperature levels (90°-120°C) for both water pumping and air conditioning applications. At these low operating temperature levels, the efficiency of the engines is low, so that a relatively large area of collector is required for a specific power output. It is, therefore, doubtful that solar power units using flat plate collectors will find wide use except in very remote power applications where system simplicity is of paramount importance.

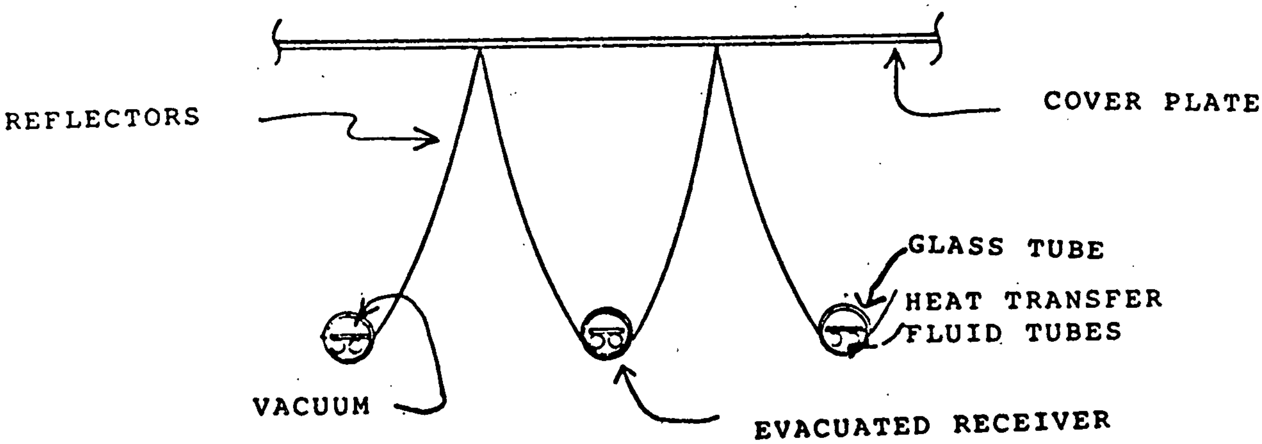
The efficient operation of organic Rankine cycle engines can, however, be accomplished with relatively moderate heat input temperatures of 120°-300°C which can be achieved with low levels (2X-10X) of solar concentration.

There are several options available for low level focussing which do not require any tracking and/or only periodic adjustments in tilt angle. An example of one such arrangement, shown in Figure 4.1 is the Compound Parabolic Concentrator (CPC). One advantage of this collector arrangement is the outer glass or plastic plate which protects the reflective surfaces from dirt and sand. The CPC optics are such that it can utilize solar radiation over a wide acceptance angle (the magnitude depending on concentration ratio). Consequently, the collector need not track the sun on a daily basis and can accept a portion of the diffuse radiation. This collector is in an advanced development stage at the Argonne National Laboratory, and several industrial firms have license agreements which will probably lead to its near-term commercial availability.

Low level concentrators can achieve annual efficiency levels of 35% to 55% at temperatures of 120°-220°C, which are consistent with the operation of Rankine cycle engine systems.



a) USING CONVENTIONAL FLAT PLATE ABSORBER



b) USING EVACUATED GLASS TUBE RECEIVERS

CHARACTERISTICS:

- Accepts radiation over a wide angle (27.2° for a 3X concentrator), increasing efficiency and minimizing the number of tilt adjustments.
- Reflectors are protected by the cover plate, improving efficiency and reliability.
- No tracking required, simplifying installation and operation.

SOURCE: Arthur D. Little, Inc.

Figure 4.1 CPC COLLECTOR CHARACTERISTICS

B. Linear Concentrators

Three types of medium level concentrators either in use or in an advanced stage of development are;

- Parabolic Troughs,
- Segmented Mirrors, and
- Fresnel Lenses.

The most widely used of these designs is the parabolic trough collector, shown in Figure 4.2. The cross section of the reflector perpendicular to the major axis of the collector is a constant paraboloid which focusses the solar energy on a line. The linear receiver is rigidly located at the focus of this parabola.

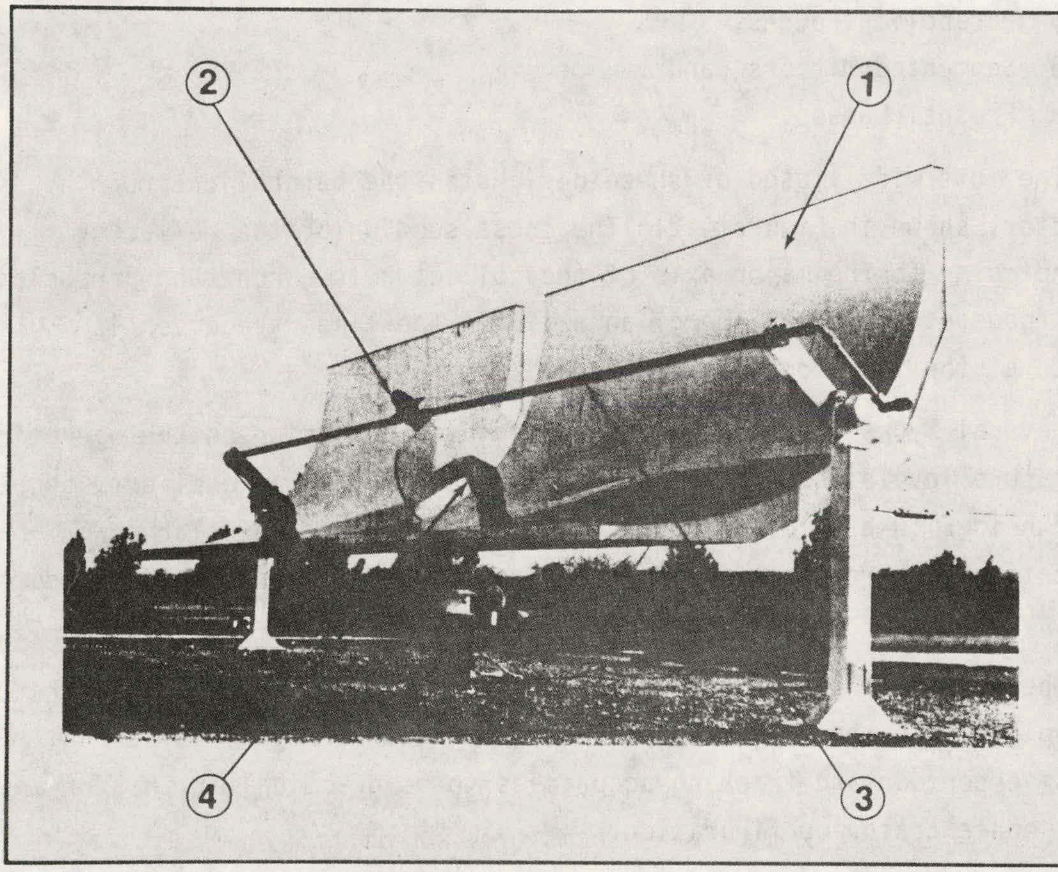
Several types of receivers are being used depending on the operating temperature levels under consideration. Evacuated tube receivers, such as shown in Figure 4.1b, are often considered for use in solar power applications, where there is an incentive to operate at elevated temperature levels.

The geometric concentration ratios for parabolic trough concentrators are typically in the 20X-40X range. Higher concentration ratios require excessive contour and tracking accuracies to be practical in this or any linear concentrator configuration.

Parabolic trough collectors are generally considered for operation in the 100°-300°C temperature range.

C. Point Concentrators

As previously mentioned, practical linear concentrators can achieve concentration ratios of 20X-40X and operate at temperatures of 100°-300°C. Point concentrators with similar tracking and geometrical accuracies can achieve concentration ratios of 400X to 1600X and the higher temperatures required for efficient operation of thermal engines. However, this higher concentration ratio capability requires two axis tracking, which considerably complicates the design and operation of point concentrating systems as compared to linear concentrators.



1. REFLECTING LIGHTING SHEET
2. SHADOW BAND TRACKER
3. ABSORBING RECEIVER TUBE
4. MOTOR DRIVE

SOURCE: ACUREX AEROTHERM PRODUCT LITERATURE

Figure 4.2 Parabolic trough collector

There are two basic approaches to high concentration systems being investigated;

- Central Receiver, and
- Distributed Collector.

A central receiver system (also known as the "power tower" concept) utilizes a large number of individually guided mirrors (heliostats) placed in an array at the base of a tall tower (such as indicated in Figure 4.3). The incident solar energy is reflected from the mirrors to a receiver mounted on top of the tower, where it is absorbed by a heat transfer medium (usually steam). The steam so generated can be used to operate a conventional steam power plant.

The major cost component in such a system is expected to be the heliostats which require precise two axis tracking, highly reflective and geometrically precise surface contours, and structural rigidity to withstand high wind loads. Several of the heliostat concepts under development are indicated in Figure 4.4.

The primary advantage of the power tower concept is that all the solar energy from a large area is collected in a central location which greatly reduces the requirements for piping of heat transfer fluids over large distances as compared to systems using a distributed collector array (troughs, etc.). Also, due to the high levels of solar concentration involved (1000X-2000X), it is possible to attain temperatures consistent with the operation of conventional steam power systems (400°-600°C).

The power tower system is most often considered for use at high power levels (50 megawatt and higher) in regions where a particularly high percentage of the insolation is direct. However, the use of a mini-power tower for individual irrigation pumping systems at the 150 kW power level which might be applicable for use in remote areas is also being investigated.

Another approach to high level concentration is the use of parabolic dish concentrators. One such system is shown in Figure 4.5. In this

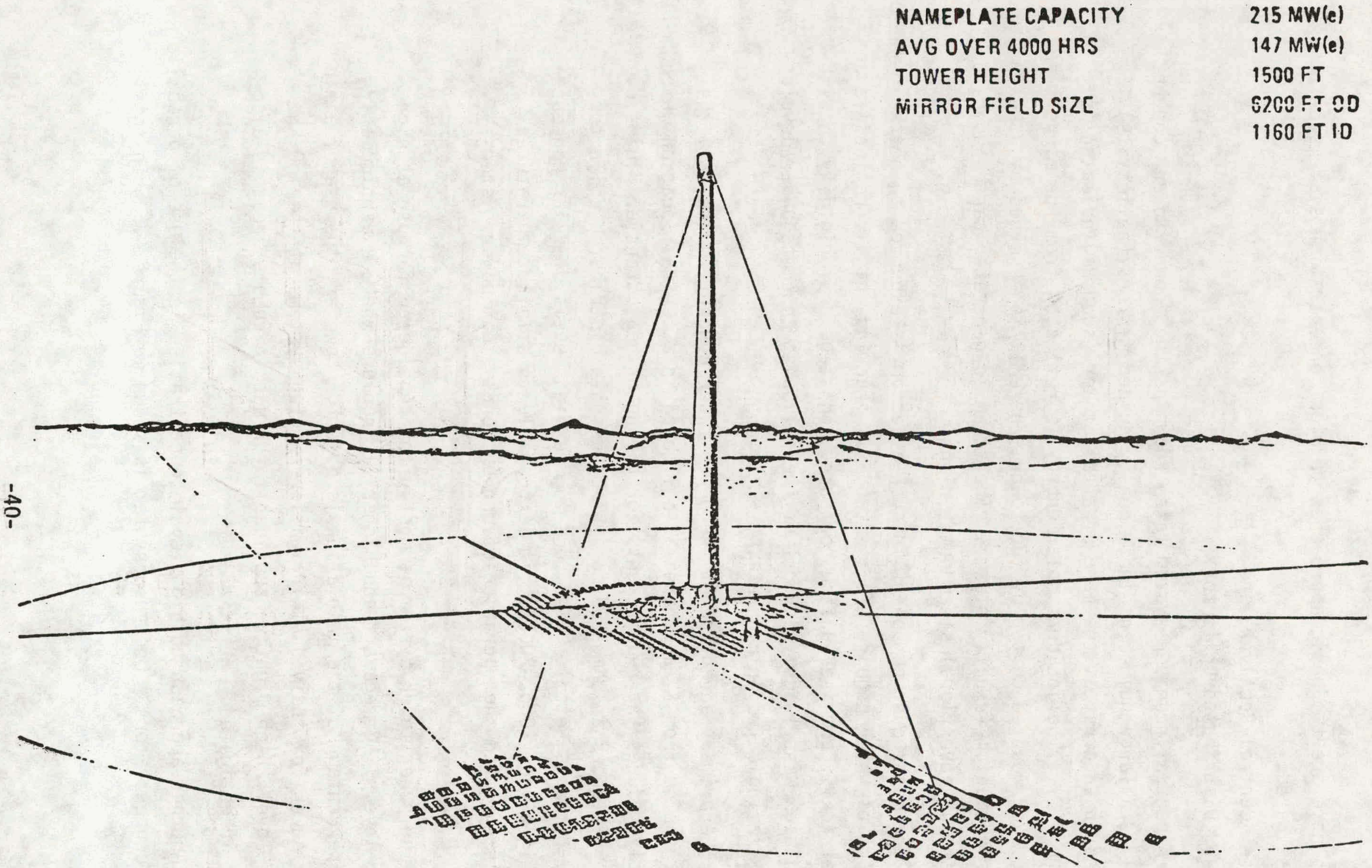


Figure 4.3 CENTRAL RECEIVER CONCEPT

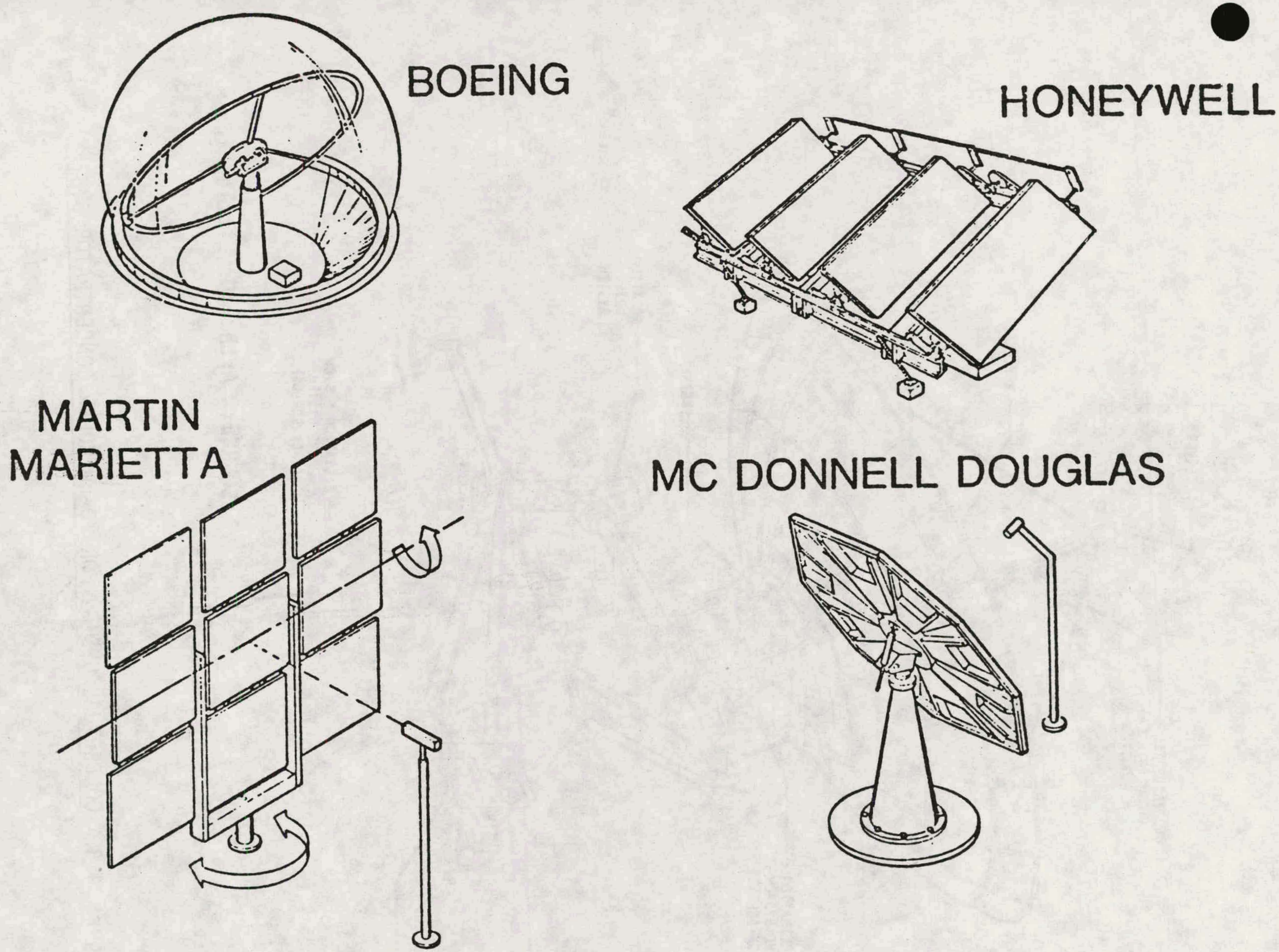
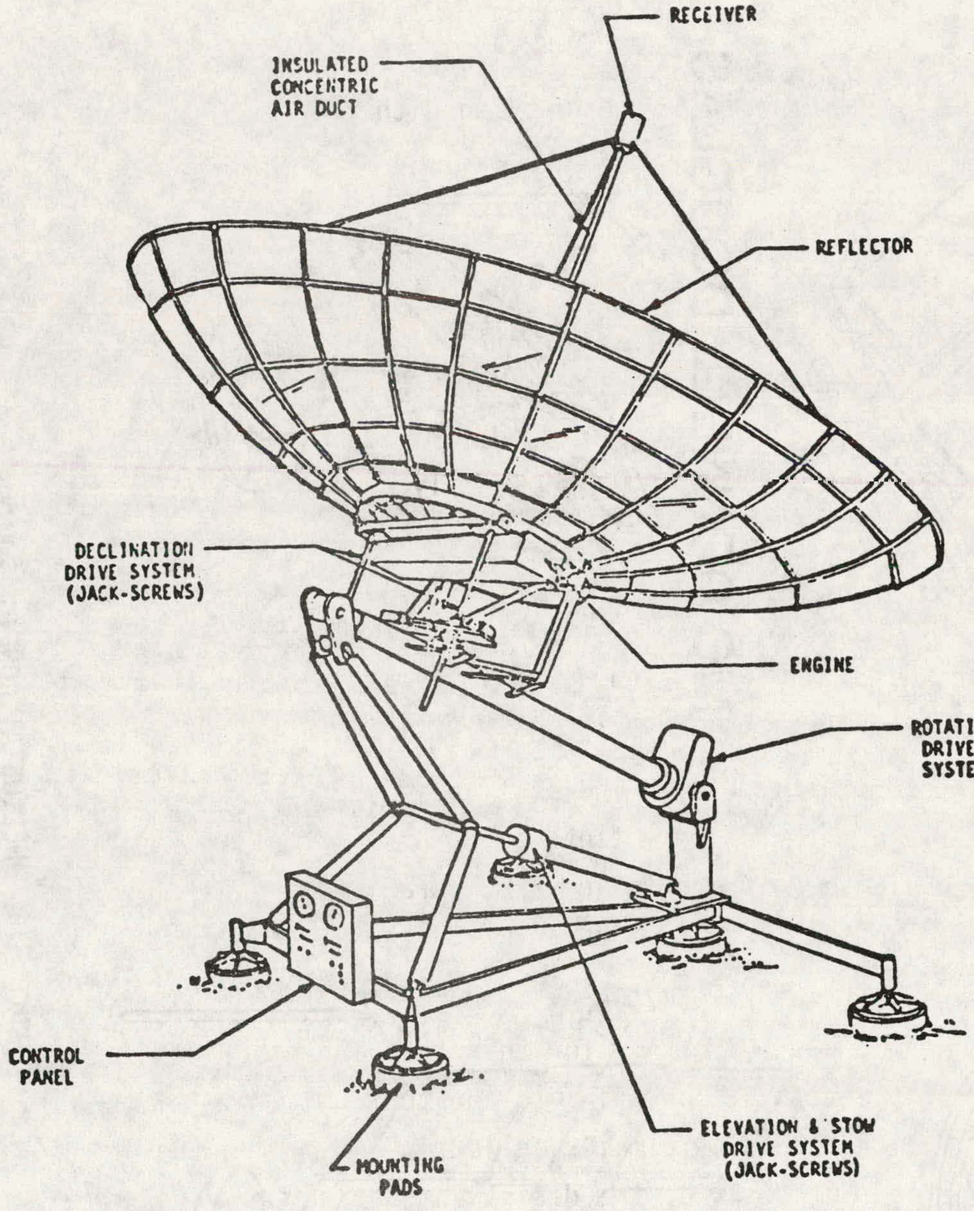


Figure 4.4 <u>HELIOSTAT CONFIGURATIONS</u>



SOURCE: Arthur D. Little, Inc.

Figure 4.5 CONCEPTUAL DESIGN FOR 10-kW SOLAR CONCENTRATOR SYSTEM

system the concentrated solar energy is used to operate an open Brayton cycle engine, thereby eliminating the need for a heat rejection system as required by Rankine cycle engines. Brayton cycle engines (which require temperature levels in excess of 600°C for efficient operation) are also being considered for use in conjunction with the power tower point concentrator system previously described.

D. System Performance

There is a wide range in the projected thermal/economic performance of the various collector/heat engine solar power options being investigated. In general, the higher concentration systems (such as the power tower) are projected to have more favorable performance-characteristics than lower level concentrator systems due primarily to their ability to operate at higher temperatures and thereby, higher efficiency levels. On the other hand, these high concentration systems may entail a higher degree of risk due to uncertainties in the nature of solar radiation (discussed in Section 2.1) and the requirements to maintain precise two axis tracking under severe environmental conditions.

The type of systems which are in the most advanced development stage at this time by virtue of their use in several demonstration projects in the United States and elsewhere are those using parabolic trough collectors and organic Rankine cycle engines.

The projected annual system efficiency of this system combination is presented in Figure 4.6. As indicated, for this (and any other collector-engine combination), there is an operating temperature which maximizes system efficiency and therefore, minimizes collector array area requirements for any specified output. For the design considered, the system efficiency under average clear day solar flux conditions in sunny regions of Peru is about 14% and occurs at an operating temperature of about 300°C. By comparison, the efficiency of a system using flat plate collectors would be only about 4-5%. The efficiency vs temperature curve is fairly flat, and there may be practical advantages for operating the system at as low a temperature as possible, consistent with acceptable efficiency

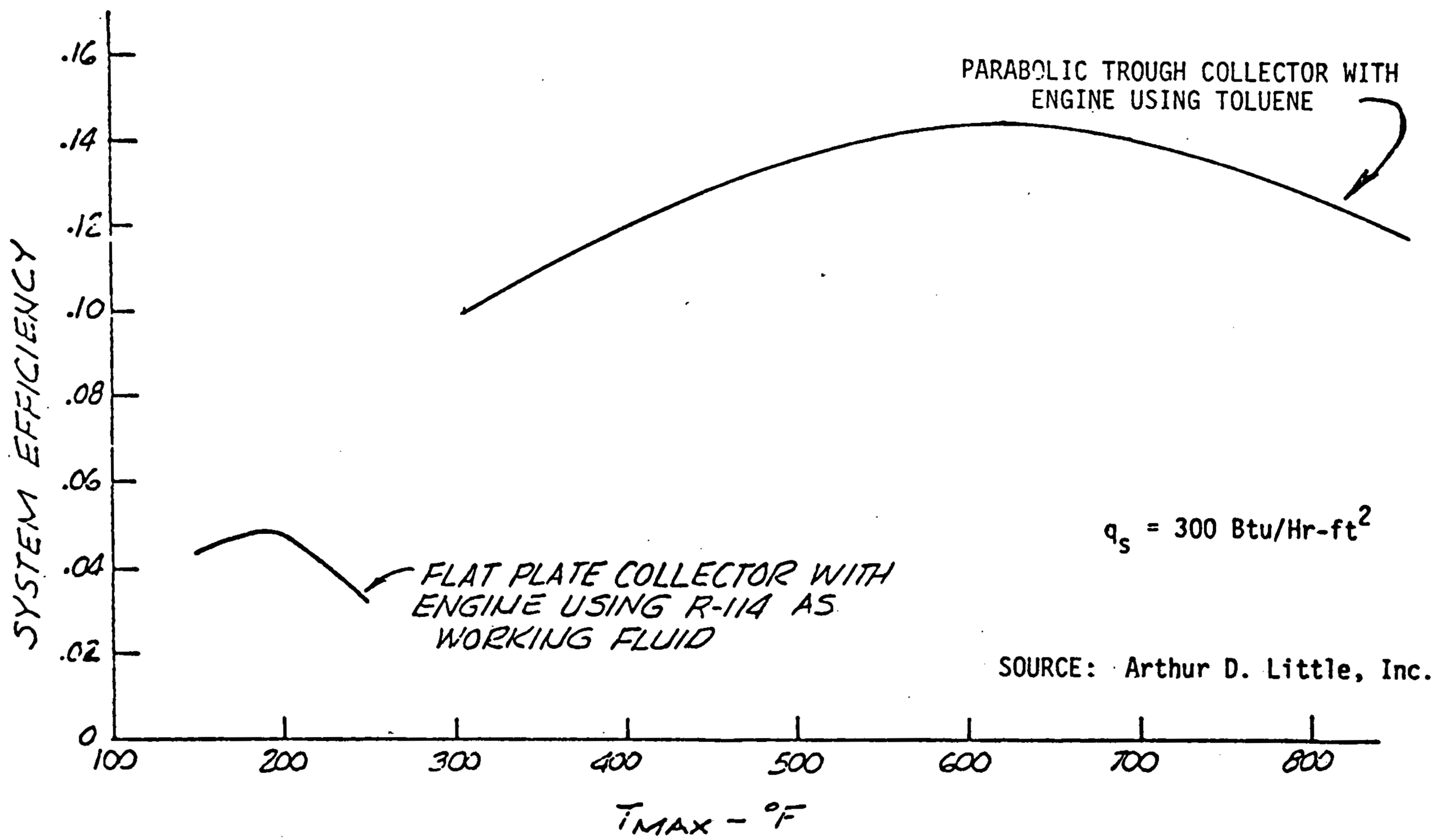


Figure 4.6 OVERALL SYSTEM EFFICIENCY

levels. Such considerations include the ability to use a hot water thermal storage system (limited by operating pressures), and choice of materials of construction (pumps, valves, etc.).

4.3 Cost Projections

To date, there has been very limited experience with establishing the commercial cost of solar thermal power systems. Thus, there is a wide variation in cost projections for the different system options.

The system options for which costs are probably best established is the parabolic trough/organic Rankine cycle engine combination previously discussed. It is expected that these costs will be representative for other distributed system arrangements (segmented mirrors, CPC, etc.).

Manufacturers project that the cost of parabolic trough collectors might approach $100 per square meter in production quantities. The cost of organic Rankine cycle engines is expected to be in the $500 to $1000 per kW range depending on capacity. The resultant system cost on an installed basis is estimated in Figure 4.7. As indicated, installed system cost would approach $2000 per peak kW (i.e., no storage), based on the assumptions shown. The installation costs are significant and probably the most difficult to estimate due to variations in labor costs, site preparation, etc. The systems could, however, be installed with Peruvian labor, thereby minimizing foreign exchange costs.

In the power tower system, the major cost factors are the heliostats used to redirect the solar energy to the centrally located receiver. Current heliostat cost experience is approximately $285 per square meter based on a purchase of 144 heliostats for a thermal test facility located in Albuquerque, New Mexico. However, ongoing low cost heliostat development activities indicate that production cost goals of $70 to $150 per square meter can be achieved.

Based on this large scale production cost estimate for heliostats, it is projected that the installed central receiver power system would have a cost of $1300 to $1500 per kW. Assuming successful operation of the Barstow pilot plant facility, these cost goals may be achievable

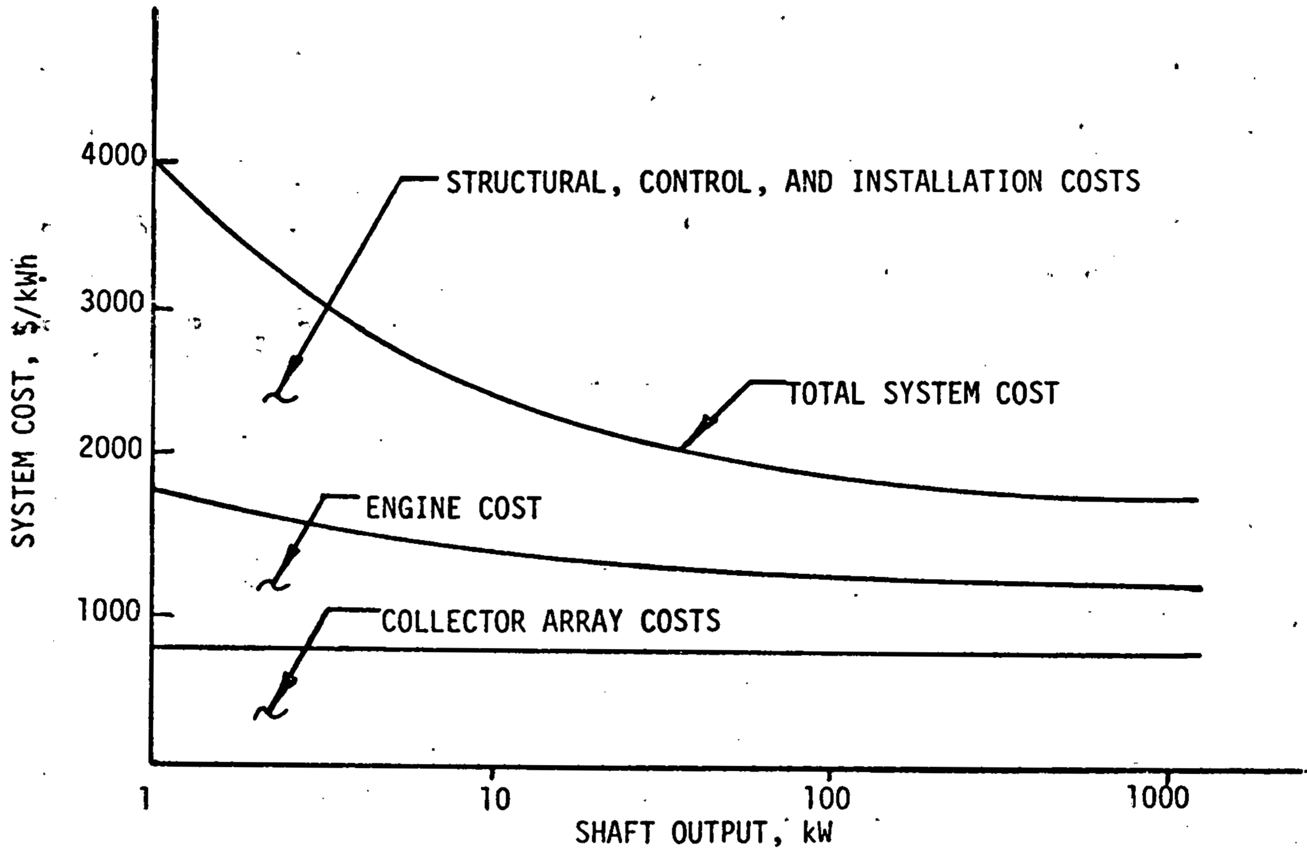


Figure 4.7 COST OF A DISTRIBUTED SOLAR THERMAL POWER SYSTEM

by the mid to late 1980s.

4.4 Economic Performance

The cost of power from a solar power unit is a function of many variables including;

- Initial cost,
- Annual power output,
- Operation and maintenance costs,
- Interest rates, and
- Depreciation (useful life).

The cost of power generated by the parabolic trough/ORC engine system combination when operating in areas of favorable solar flux (such as Piura) is shown in Figure 4.8, assuming;

- Interest Rate - 8%
- Useful Life - 25 years, and
- Annual O&M Operating and Maintenance Cost of 4%.

The cost of power produced by the system is in the 15¢-25¢/kWh range if both labor and purchased component costs are considered. The cost of power decreases with increasing system capacity due to the economies of scale indicated on Figure 4.7. This cost of power is still significantly higher than that from large central utilities but approaches that from small Diesel units often used for pumping and power generation in remote areas, particularly if anticipated increases in fuel costs occur.

Power costs from larger central receiver power systems are projected to be in the 5¢-15¢/kWh range if the lower end of the heliostat cost goals are attained. These relatively low power cost projections reflect, in part, the large size of these power units and the assumption of large scale production of key subsystems (in particular, the heliostats).

For both distributed and central receiver solar power options, over 50% of the cost would be labor associated with subsystem manufacture and installation. This factor would greatly reduce the foreign exchange requirements of this power option and lead to substantially lower power

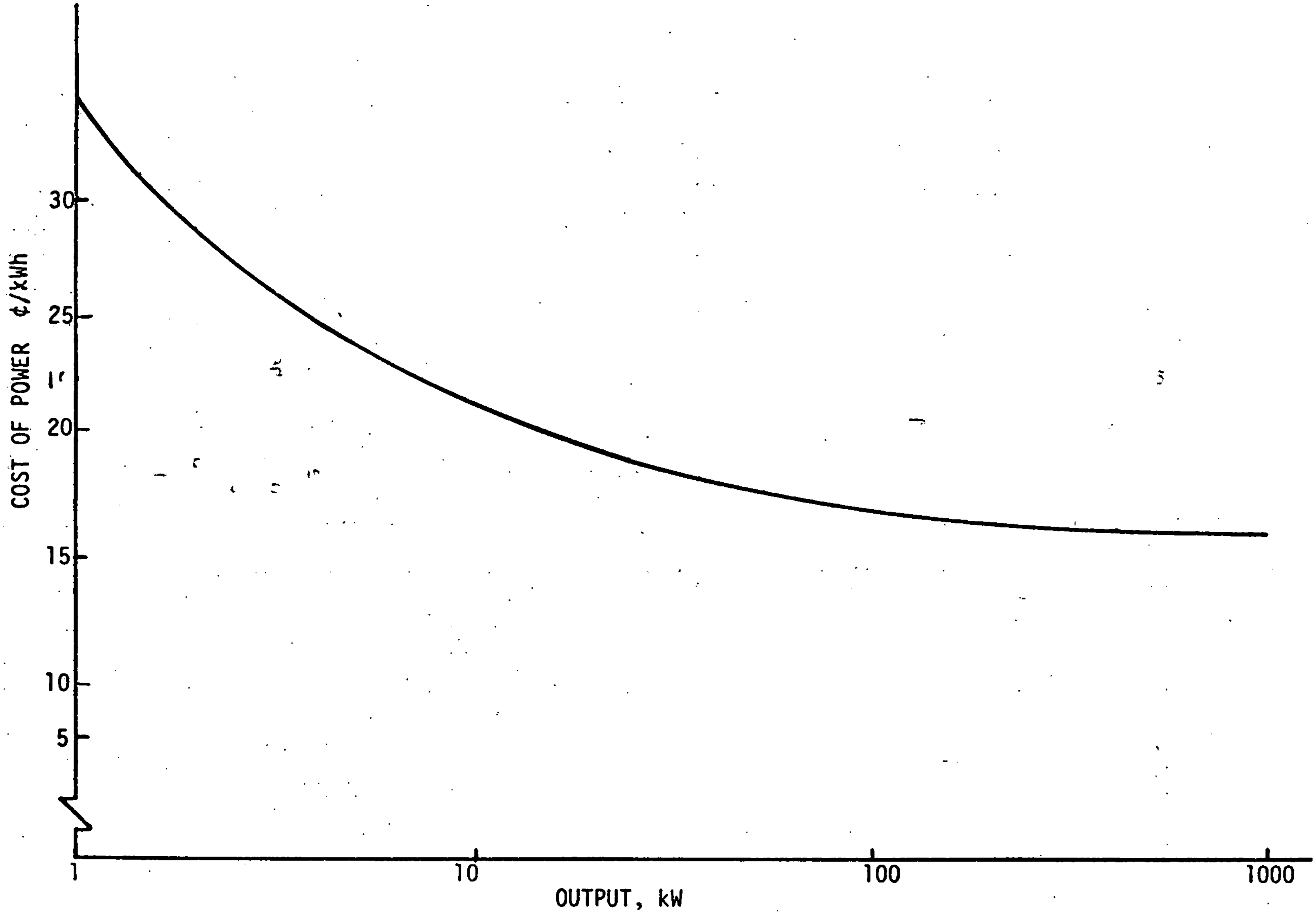


Figure 4.8 COST OF ELECTRIC POWER FROM SOLAR THERMAL POWER SYSTEMS

costs than indicated above if only foreign exchange costs are considered.

4.5 Implementation Options

Most applications which are appropriate for solar thermal power systems can also be served by the photovoltaic power systems discussed in Section 5.0. As a practical matter, therefore, these two technology options will be competing with one another over a range of applications including water pumping, air conditioning and refrigeration, and village electrification.

Which types of systems will be implemented to the greatest extent will depend on the relative progress made in lowering costs and on field experience with the different system options. For purposes of this preliminary study, solar thermal power and photovoltaics have been classified under the common heading of direct solar power systems (to differentiate them from the wind and biomass options). The implementation rate and impacts projected in Section 5.0 for photovoltaics may in practice include a combination of photovoltaics and solar thermal systems, and therefore, no separate implementation scenario is developed here for solar thermal power.

Also, the requirements for reflectors, concrete foundations, support structures, etc. are not greatly different for the collectors of a solar thermal system as for those of a photovoltaic system using solar concentration (in fact, the concentrator subsystems could be identical). The resource requirements for the photovoltaic options are, therefore, assumed to also apply to the solar thermal option.

As a general rule, photovoltaic systems would be used for very small systems (less than 5 kW peak capacity) to avoid the mechanical complexities associated with solar thermal electric power generation. For very large systems (5 MW peak and larger) that might be of interest to a central utility, solar power generation must usually compete with large scale hydro. Unless the economics of solar power generation improve beyond expectation, only systems in the 5 kW to 1 MW size range will be utilized, mostly in rural areas.

Due to the nature of the applications outlined above, the central receiver type systems will find limited application in Peru, since the economies of scale associated with these systems are evident at relatively high power output, (these systems are primarily being investigated for power outputs of 50 megawatts and larger). Also, uncertainties in the nature of solar radiation (Section 2.1) may decrease performance, making the economics look even less promising.

These simplifying assumptions will have to be reviewed in future program phases in order to more carefully indicate the relative merits of the solar thermal and photovoltaic power options given the environment and resources of Peru.

5.0 PHOTOVOLTAICS

5.1 Background and Status

Solar cells are semiconductor devices which convert solar energy directly into electricity, as depicted in Figure 5.1. These devices require no moving parts, as do thermal power systems, and have demonstrated long-term reliability in both space and terrestrial applications.

The present cost of terrestrial solar cell panels is $12-$30 per peak watt,* depending on quantity purchased. In spite of this high cost, solar cell panels are increasingly being used for remote power applications, such as mountain top communication equipment and cathodic protection of pipelines. The worldwide market in 1977 for such applications was estimated to be 750 kW annually and is projected to increase rapidly in the future. The cost of solar cell panels is expected to decrease dramatically over the next 10 years; the goal of the United States Department of Energy is to reduce the cost of solar cell panels to $2.00 per peak watt in 1982, $0.50 per peak watt in 1986, and $0.15 - $0.30 per peak watt in 1990-2000. The lower end of these cost goals will be quite difficult to achieve, given the very low unit area costs they imply (∿$1.50 - $3.00 per square foot) and the need for rugged weather resistant construction. However, there is a high probability that a cost of $1.00 - $2.00 per peak watt can be obtained in the early 1980s by using solar cells combined with solar concentration. By using solar concentration, costly solar cell area can be replaced by relatively inexpensive reflector (or lens) area. As the cost of solar cells falls to the point where reflector area costs as much as solar cell area to achieve a given output, there will be no incentive to use solar concentration and most solar cell arrays will then be of the flat plate variety.

Numerous photovoltaic material combinations involving several fabrication processes are being investigated by corporate, government, and

* Power output under high solar flux conditions associated with operation at noon on a clear day (specifically, 1 kW/m^2).

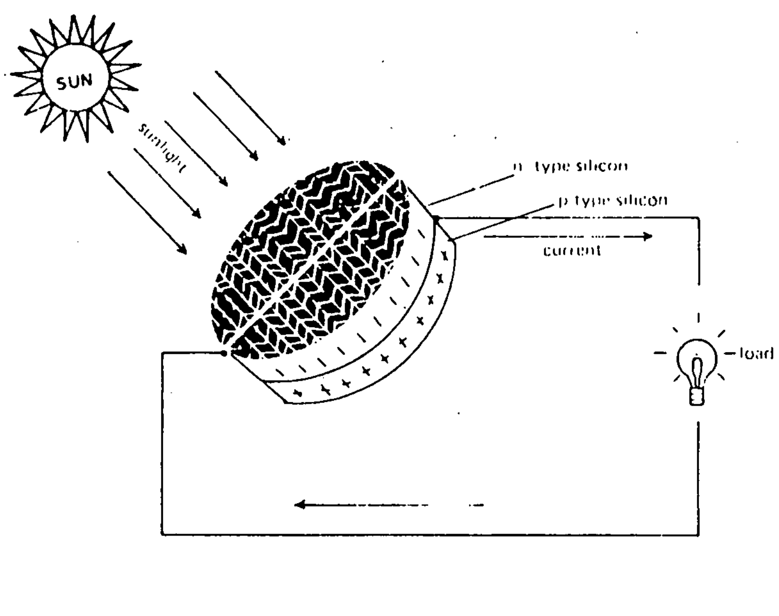


Figure 5.1 **Schematic of solar cell operation**

academic organizations. However, most solar cell panels now in use (for both terrestrial and space applications) utilize single crystal silicon, due to its demonstrated high reliability, long life, and relatively high efficiency.

It is expected that in the near to intermediate term (5-10 years), most solar cells will continue to be made from single crystal silicon, using steadily improving material purification and cell fabrication techniques to lower costs. This well-proven and highly reliable material shows the potential for achieving the 1985 goal of $0.50 per peak watt. The electrical output characteristics of a silicon solar cell are shown in Figure 5.2. As indicated, they generate about 0.5v at the optimum efficiency point. Generating elevated voltages requires connecting a multiplicity of individual cells in series. Output voltages of solar cell panels, which typically measure 2' x 4', are generally 12v to 24v. The efficiency of individual cells in converting solar energy into electricity is typically 11%-15%; however, when the packing density of cells within a panel and resistance losses are taken into account, the efficiency of panels is usually around 10%.

Alternative materials to single crystal silicon which are farthest along in their development are gallium arsenide, cadmium sulfide, and amorphous silicon. The primary incentive for developing these alternatives is that they can be effectively utilized in very thin films (2μ to 10μ), which is consistent with low cost manufacture.

Although there are numerous R&D programs sponsored by both government and industrial organizations to improve the performance of these alternative materials, none of them is sufficiently far advanced to have a significant influence before 1985.

Solar concentrators are being developed over a wide range of concentration levels for use in solar thermal systems, where the high temperatures resulting from concentration have thermodynamic advantages. For the most part, solar concentrators for use with solar cells will be similar to those developed for thermal systems (discussed in Section 4.0),

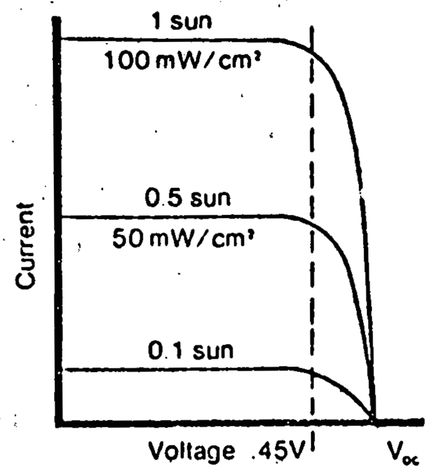


FIGURE 5.2 SOLAR CELL PERFORMANCE

except that the thermal receiver placed in the focal plane will be replaced by a properly designed solar cell array.

Concentrator systems range from simple flat reflectors to refractive Fresnel lens systems and parabolic dishes. The type of concentrating system utilized is largely dependent on the level of concentration desired. The flat plate or passive reflector is basically a planar reflector for concentration ratios up to 2X. Compound parabolic concentrators are best suited for concentration ratios in the 2X - 10X range. Linear concentrators, such as parabolic troughs, can best be utilized for concentration ratios in the 10X - 40X range. For concentrating systems greater than 40X, point concentrators (parabolic dishes, etc.) are used.

5.2 Description of System

There are two important factors which must be taken into account in the design of a photovoltaic power system.

- Power is produced by the solar cells only when the sun is shining. The output of the solar cell array is, therefore, highly variable even on a clear day, peaking at solar noon and falling to about one half the peak power 3 hours either side of noon. Little or no power is produced during periods of cloudy weather. The highly variable nature of power output from the solar cell array requires energy storage (batteries, hydro-storage, etc.) for most applications, and
- The output from the solar cell array is in the form of direct current power. Many on-site applications which may be of interest in Peru (irrigation pumping, refrigeration, etc.) can use DC power; however, before this power can be used by conventional appliances it must be converted to AC power of the appropriate voltage and wave form.

A schematic of a photovoltaic power unit that accounts for the above factors and is capable of integrating with a conventional AC power system is shown in Figure 5.3. This system consists of;

- Solar cell power modules that make up the collector array (shown as a flat plate),
- A mounting rack to properly orient the solar cell modules (tracking systems would be used with concentrating designs),
- A DC-AC inverter to convert DC output of the solar cell array and the battery storage into AC power consistent with operation of conventional electrical appliances,
- AC switchgear to ensure a proper phasing of power supplied by the photovoltaic power unit and utility power,
- A controller (consisting of DC switchgear and central circuits) which controls the selection of load alternatives between the direct use and storage,
- A storage subsystem to store excess power produced during peak solar flux periods for later use. The storage is shown as a battery pack which is the most likely storage approach in the near-term, and
- Wiring to connect solar cell panels in the proper series-parallel arrangements.

Most of the cost of solar cell power systems is now associated with the solar cell array itself, due to the present high cost of solar cells. As the cost of the solar cells is reduced to the point where their use will be practical for general applications, the effect of the power conditioning and energy storage subsystems on overall system cost will become increasingly important.

These subsystems affect system costs in two ways;

- They are themselves rather costly components, and
- They have inefficiencies associated with their operation which lower overall system efficiency, thereby increasing the area of solar cells required for a given power output.

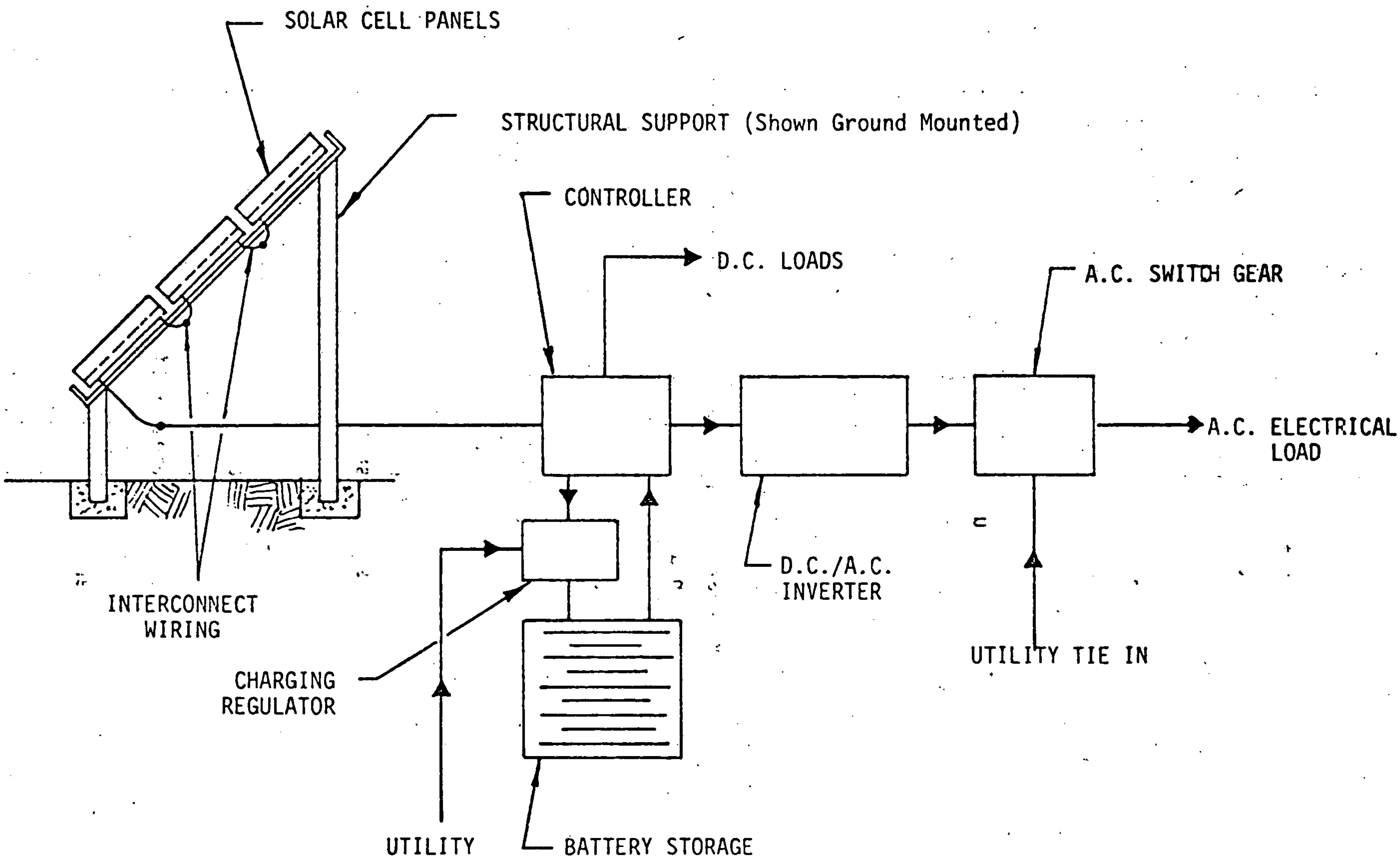


FIGURE 5.3 SCHEMATIC OF A PHOTOVOLTAIC POWER SYSTEM

Even the use of very efficient inverters and energy storage subsystems (such as batteries), will result in a 30% loss of power between the solar cell array and the ouput of the inverter system, if all power were to "cycle" through the battery. These system inefficiencies will significantly increase the solar cell area requirements (and thereby cost) for a given net system output.

5.3 Cost Projections

Most of the equipment that is used in a photovoltaic system has been manufactured on a limited basis so that basic costs are known. Because of this limited production, the unit costs of most of these components is relatively high. When a large enough market for this equipment is realized, the costs will come down as production increases. These decreases in cost are expected to occur during a 1980-1990 time frame.

5.3.1 Subsystem Costs:

The costs associated with a photovoltaic system can be broken down into four major areas;

- Solar Cell Array,
- Power Conditioning Equipment,
- Battery Storage, and
- Electrical/Mechanical Installation.

Currently the major cost of a photovoltaic system is for the solar cell array. However, in the near future those costs are expected to decrease rapidly such that the other costs associated with a photovoltaic system will become important factors in determining the overall cost of the system. A summary of the projected costs for the 1980-1990 time period for the above four areas is presented in Table 5.1. The following subsections contain a more detailed description of these costs and the reasons for the projected decreases (if any) in those costs.

(a) Solar Cell Panels/Array

Current solar cell panel costs in large quantities are in the $12-$18/p-W range, which makes photovoltaic systems economically

Table 5.1

SUBSYSTEM COST SUMMARY

	1980	1985+	1990+
Solar Cell Panels	$4/p-W*	$.50/p-W*	$.25/p-W*
Power Conditioning	$200-$1,200/kW	$100-$200/kW	$50-$100/kW
Battery Storage	$75/kWh	$50/kWh	$30/kWh
Installation			
- Panel Mounting	$3/ft^2 - flat surface $4/ft^2 - tracking		
- Electrical	$100/kW - 10% efficient arrays $ 75/kW - 15% efficient arrays		

* p-W = peak watt output at solar insolation level of 1 kW/m^2.

unattractive except for highly specialized remote power systems (communication equipment, etc.). These costs are expected to decrease to $4/p-W by 1980 and to $0.50/p-W by 1986. DOE has also set a cost goal of $0.25/p-W by the year 2000 which will require new technology to achieve. As mentioned earlier, with these cost reductions in solar panels, the costs of other parts of the photovoltaic system become important factors.

(b) Power Conditioning Equipment

The cost of inverters, as with many other pieces of equipment, is driven by the quantity or capacity manufactured. For small inverters ($\sim$10 kW) of primary interest in remote locations in small quantities, the cost is in the range of $2-0-$1200/kW. The lower end of this range is indicative of the costs of line-commutated inverters which use utility power for frequency control. The upper end of the range represents reliable, solid-state, self-commutated inverters. These are most likely the type that would be required in Peru for these applications requiring AC power.

As the production capacity of inverters increases, their costs are expected to decrease substantially, such that for small units (10 kW) in modest production the cost will be in the $100-$200/kW range.

(c) Battery Storage

Lead-acid batteries are currently being manufactured in modest production quantities for industrial applications, such as mobile electric powered equipment. The cost of these batteries for the near future (1980) will be about $75/kWh. This cost is not expected to decrease dramatically as production capacities increase. The cost of this type of battery will probably bottom out at about $50/kWh by the year 1985 based primarily on material costs. If new battery technology currently being developed is successful, battery costs may be reduced to $30-$35/kWh by the year 2000.

(d) Electrical/Mechanical Installation

Installation costs include the labor required to mount and install the solar panels/arrays and associated equipment, and the materials used for the installation.

Electrical installation consists of the materials (usually copper wire) and labor required to interconnect the solar cell arrays, the power conditioning equipment, the batteries, and the distribution to the load, as well as any special controls which may be required.

The costs associated with installation of a photovoltaic system are not expected to decrease in future years due to the basic nature of these costs. Mechanical installation costs are currently estimated to be $2-$4/ft^2 of collector area, depending on the type of system, as indicated in Table 5.1. Electrical installation costs are estimated to be $100/kW for 10% efficient solar arrays. These costs are expected to be somewhat lower for 15% efficient arrays since there is less wiring within the array itself. For this study, these costs are projected to be $75/kW for 15% arrays.

5.3.2 System Costs:

As indicated above, the cost of a system depends significantly on how much energy storage and power conditioning is required, as well as on the cost of the solar cell panels. Table 5.2 shows a typical cost breakdown per peak kW of output for a system based on two separate system designs as described below.

- <u>Case 1: No Storage or Inverters</u>. This system would use the power produced by the solar cell array directly so that the array output is the system output capacity since there are no storage or inverter losses.

  This would be consistent with applications such as water pumping or refrigeration, where no energy storage or power conditioning is required and the array output is used to drive DC motors directly. This type of application could be of particular interest in rural areas of Peru in order

Table 5.2

SYSTEM COST BREAKDOWN - 1978 DOLLARS

($/kWp-output)

	Case 1	Case 2
Solar Cell Panels ($2/p-W	$ 2000	$ 2800*
Battery Storage ($75/kWh)	--	400
Power Conditioning ($150/kW)	--	150
Total (Components)	$ 2000	$ 3350
Panel Installation/Structure ($2/ft^2)	$ 200	$ 280*
Electrical Installation ($100/kW)	100	100
TOTAL	$ 2300	$ 3730

* Increased area is due to maintaining output capacity with reduced system efficiency due to batteries and inverters.

to improve agricultural sector productivity.

- Case 2: Full Storage Capacity. The assumption used in defining this system is that all power must go through storage and the inverters. This would approach the case for a village electrification system where most of the load occurs in the evening or early morning hours.

The costs listed in Table 5.2 are based on what is expected for those components in the 1980-1985 time frame based on moderate production levels.

5.4 Economic Projections

The cost of power from any solar power generating system depends upon its output which is a function of the solar flux input to the system. Thus, the capacity of a system is rated in terms of peak watts, where system output is determined for a solar flux of 1 kW/m^2 (316 Btu/ft^2-hr) which is the theoretical maximum possible solar input to a terrestrial system. The annual power output of a system is then given by the system capacity (kW) times the annual solar flux (kWh/m^2) all divided by 1 peak watt (1 kW/m^2). A location with average Peruvian solar flux will yield 1900 kWh per kW of capacity annually. Lima will produce only about 1580 kWh/kW capacity while southern Arequipa and western sections of Puira have flux incidences sufficient to produce as much as 2530 kWh per kW capacity annually.

The annual charges (amortization, operation & maintenance) associated with operating a photovoltaic system are based on;

- Interest Rate - 8%
- Useful Life - 20 years
- O&M - 2%

The cost of power is then found by dividing these annual charges by the annual kWh produced. Power costs were calculated for 2 different system configurations each for a solar flux range from the Peruvian high to average.* The results are plotted in Figures 5.4 and 5.5 for both tracking and non-tracking systems. Each band represents a different system and the top of the band (higher cost) represents average flux and the bottom (lowest cost) high flux.

At the current solar cell panel cost of $15/peak watt, the resultant power costs are prohibitive for widespread application. As the costs of panels approach the $2/peak watt range, which is expected in the early 1980's, the cost of power from systems requiring minimal storage capacity is about 15¢/kWh for a non-tracking system to about 10¢/kWh for a tracking system located in an area of average Peruvian solar insolation, power costs reduce to about 11¢/kWh for a non-tracking and 8¢/kWh for a tracking system located in a high flux area. These costs are competitive with operating small Diesel generators (per Appendix A) even at present fuel costs. The economics of photovoltaics, therefore, appear promising in an early to mid 1980's time frame for those applications where power might alternatively be generated by small Diesel or gasoline engines. This represents a potential market in Peru where many areas are not serviced by a utility grid and do not have mini-hydro potential.

If the 1986 goals of the United States Department of Energy were achieved, the cost of power from photovoltaic systems would reduce to about 10¢/kWh for systems operating in areas of average flux and to a 5¢/kWh for those operating in high flux areas, depending upon the systems storage and power conditioning capabilities. At the lower end of the range, photovoltaics become competitive with all fuel fired power plants, but probably not with hydropower unless the cost of transmission from viable hydrosites is very high.

5.5 Implementation Options and Energy Impacts

Because of the relatively low cost of hydropower and Peru's efforts to connect more of the power generating systems to a common grid, photovoltaic power systems are feasible only in remote areas which have no

* It was assumed that photovoltaics would not be considered in locations such as Lima, which have low annual insolation levels.

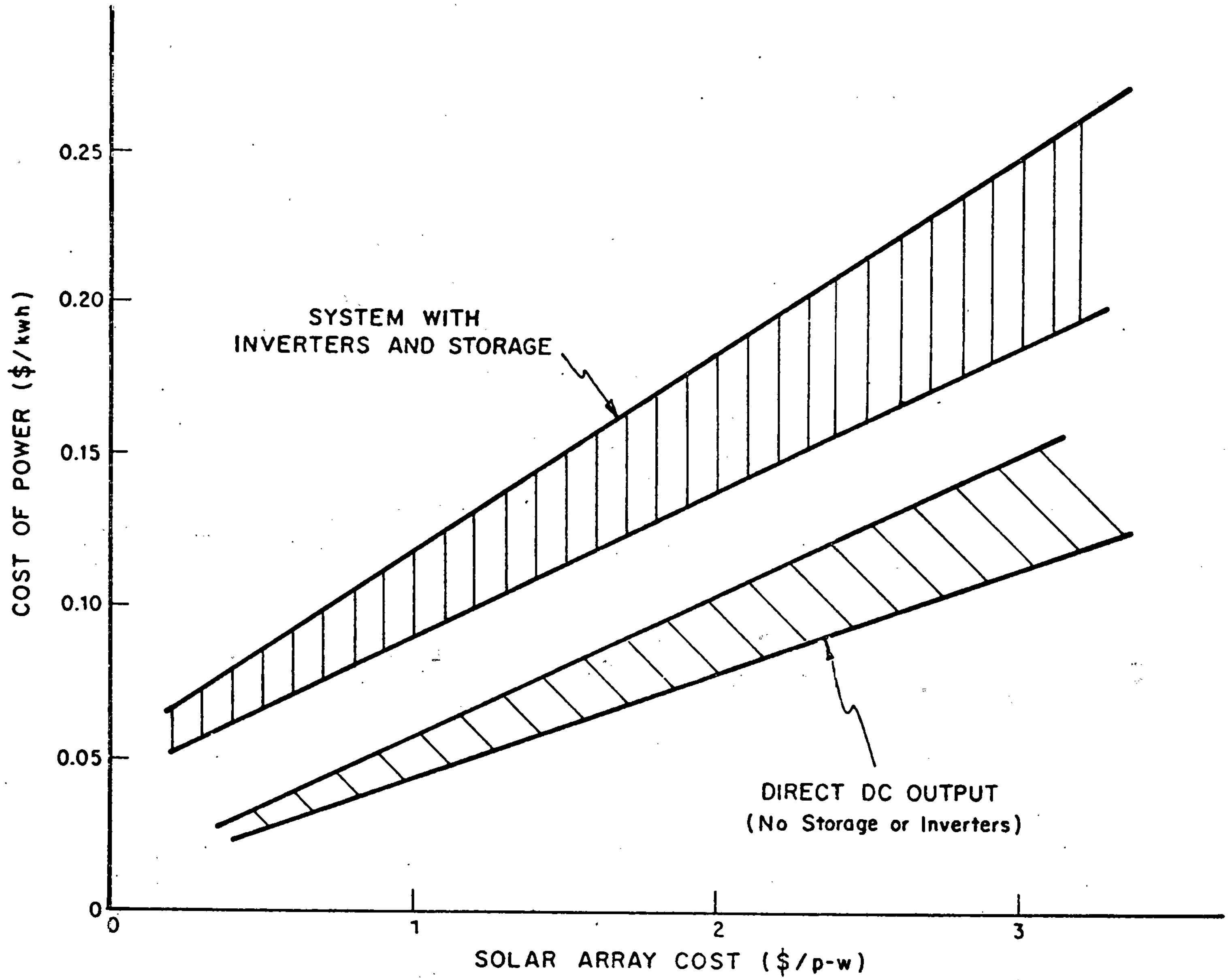


FIGURE 5.4 COST OF POWER FOR A TRACKING SYSTEM

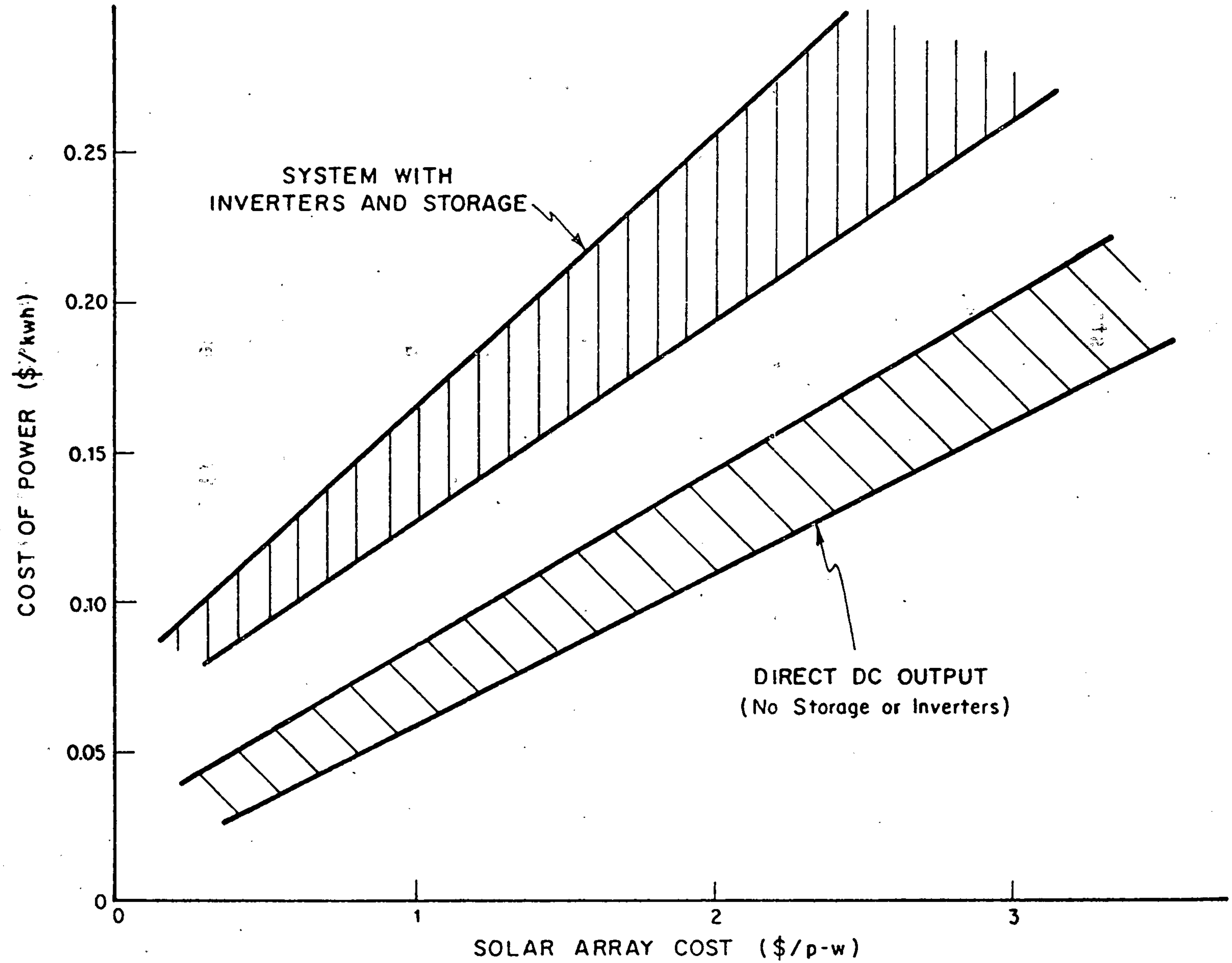


FIGURE 5.5 COST OF POWER FOR A NON-TRACKING SYSTEM

viable hydro resources, and/or the cost of extending the grid is prohibitive. Today, 48% of Peru's 16 million people live in rural areas most of which have no electricity. The introduction of electricity in these areas would improve rural productivity and raise the standard of living which may, in turn, lead to a more stable rural population. Also, the use of electric lighting would displace that of kerosene-burning lamps.

The implementation rate for photovoltaic power units indicated in Table 5.3 assumes that;

- In the 1980-1990 time period small photovoltaic power units are installed in villages to provide small amounts of power to critical functions such as water pumping (for cattle), small village industries, and lighting, and
- In the post 1990 time period, the cost of photovoltaics is reduced to the level where they are used to replace or supplement power generated by Diesel engines in both pumping and electric power generating applications.

As a result of the implementation scenarios of Table 5.3, the cumulative capacity of installed photovoltaic systems and their power output in two Peruvian solar insolation regimes are indicated in Table 5.4. Based on the results of the scenario considered and Peru's projected capacity requirements, photovoltaic power would satisfy less than 1% of Peru's power even by the year 2000.

The assumptions leading to this low impact would require review should the extent of mini-hydro resources not be as high as expected and/or the cost of connecting the grid to larger hydropower resources prove prohibitive.

5.6 Resource Requirements

Table 5.5 provides a preliminary indication of the resource requirements of the implementation scenarios. The resource requirements indicated are consistent with the use of a 5X concentrator using the compound parabolic concentrator design.

Table 5.3

IMPLEMENTATION SCENARIO

	Number of Units	Size, kWp	Capacity, kWp
1985	200	2	400
	5	100	500
			900
1990	200	4	800
	20	100	2000
			2800
2000	300	4	1200
	50	100	5000
			6200

Table 5.4

ENERGY IMPACT OF IMPLEMENTATION SCENARIO

	Installed Capacity	Annual Power Generation (10^6 kWh)	
	MW	Avg. Flux	High Flux
1985	2.3	4.4	5.8
1990	11.6	22.0	29.3
2000	55.6	105.6	140.7

Table 5.5

RESOURCE REQUIREMENTS OF PHOTOVOLTAIC IMPLEMENTATION SCENARIO

	1985	1990	2000
	ANNUAL MATERIAL REQUIREMENTS (tons)		
Glass	120	380	840
Aluminum	70	200	450
Steel	180	550	1210
Copper	20	40	90
Cement	200	620	1360
	ANNUAL MANPOWER REQUIREMENTS (man-years)		
Management/Technical	5	10	25
Production & Installation	30	85	190
Operations & Maintenance	5	25	115
	ANNUAL FINANCE REQUIREMENTS (1978 \$ x 10^6)		
Solar Cells	.4	.5	.6
Materials & Comps. (w/o solar cells)	.5	1.5	3.3
Labor (Fabrication & Installation)	.3	.9	2.0
O&M	.5	.3	1.2
TOTAL	1.7	3.2	7.1

The resource requirements that would be associated with systems using other solar cell panel configurations (i.e., flat plates, parabolic trough, Fresnel lens, etc.) would depend on the material and labor requirements for the selected configuration. For example, with a flat plate panel the aluminum used for reflector area would be replaced by solar cell area. If solar cells are to be imported, this would increase the foreign exchange component of system manufacture.

For the case considered, the major material requirements are for steel, glass, aluminum and concrete. The steel is used for both structural support and as an enclosure for the solar cell and reflector subassemblies. Concrete is required for the collectors support foundations.

A major portion of the financial requirements are associated with labor or materials other than solar cells. In fact, the percentage of total costs associated with the solar cells decreases in time as the cost of solar cells decreases due to the worldwide R&D efforts and increased production quantities. This system (common with other arrangements using concentration) has the advantage, therefore, of having a large (and increasing) value added by Peruvian resources.

6.0 WIND POWER GENERATION

6.1 Introduction

Wind energy conversion has been practiced for centuries; there presently exist over 150,000 wind power systems in the United States alone. Small units (less than 15 kW) have a well-developed technology and a growing worldwide market (estimated at $2-$5 million annually) that includes over ten established manufacturers in the United States, Europe and Australia. In Peru, the use of small wind-powered water pumps is fairly widespread in Puira and Arequipa, providing a good basis for more widespread use of wind powered pumping and electricity-generating systems.

There are presently many agricultural areas in Peru which require water pumping for irrigation. Efforts to expand crop lands by the introduction of water are presently being made, especially in the desert section of Piura. Large and small wind pumps could play a large part in these efforts.

The performance, and therefore the cost of power, of a wind turbine system is quite sensitive to the wind regime of its location, since the energy available to a system is proportional to the cube of the wind velocity. Normally, a wind generator is practical only in areas where the average wind speed is greater than 4.5 m/s (10 mph). Several stations in Peru report average annual winds in excess of this threshold level (for example Chiclayo and San Juan). This is indicative of a reasonably good wind power potential in Peru.

Because the proximity of a hill or trees can so greatly affect wind velocity in a given location, a station's measurements can be somewhat misleading. Other suitable locations may exist in remote areas, where there is a need for power but where an extension of the existing grid is prohibited by its great expense. For this reason, the wind resource estimates outlined below may be somewhat conservative. That there are presently wind energy conversion systems in Peru supports the feasibility of wind turbine implementation.

6.2 Design Options

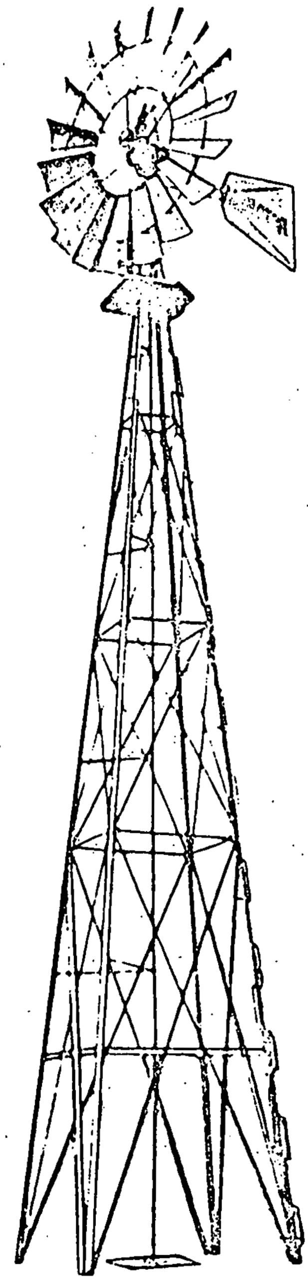
Various designs for small system (those with rated power outputs of from 1-15 kW) have been developed, including multi-bladed, low speed, high torque configurations for water pumping applications. Figure 6.1 shows such a machine that is manufactured in the United States, but which is basically the same as those in operation in Peru. There are several kinds of high speed wind turbines, (including some recent vertical axis designs) but those with proven reliability and established economics are of a horizontal axis design (Figure 6.2). Such units are commercially available, with rotors of 2 or 3 blades that are from 1.5 to 8 m in diameter.

In order to lower the cost of electric power generated by wind turbines, large units with outputs in the 100 - 200 kW range (Figure 6.3) are currently being demonstrated in the United States today, and larger MW size units, with rotor diameters of 60 - 90 m, are under development.

Figure 6.4 shows a small wind turbine generator as it might be tied in with a Diesel generating facility such as commonly used in areas not serviced by a utility grid. Battery storage is used to flatten short-term transients in power output from the generator. Since the output of a large wind turbine is constant frequency power, an inverter would be necessary only if battery storage was used (large grid connected systems won't require storage).

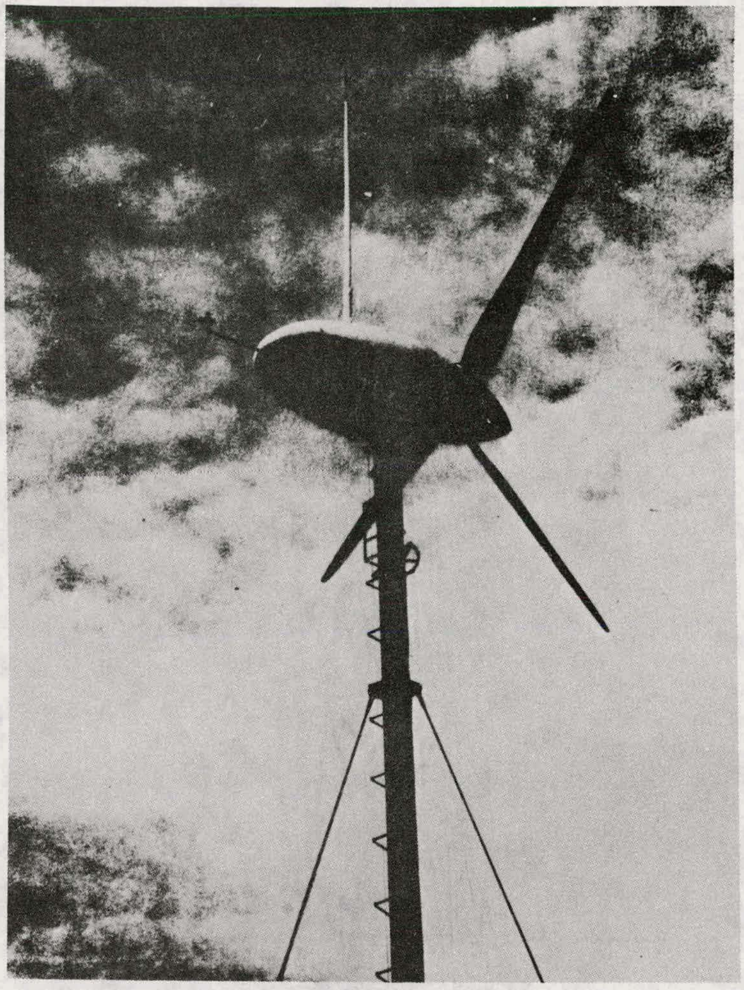
6.3 Economic Considerations

The economies of scale associated with wind turbine systems are illustrated in Table 6.1. The 6 kW cost numbers are current United States market prices less 25%, reflecting expected cost reductions associated with higher production levels. The two large systems costs are based on studies of utility sized systems produced in small quantities, and assume no significant improvements in technology. The annualized costs



SOURCE: Aeromotor, Inc.

Figure 6.1 MULTI-BLADE, LOW-SPEED WATER PUMPING UNIT



SOURCE: University of Massachusetts

Figure 6.2 HORIZONTAL AXIS WIND TURBINE

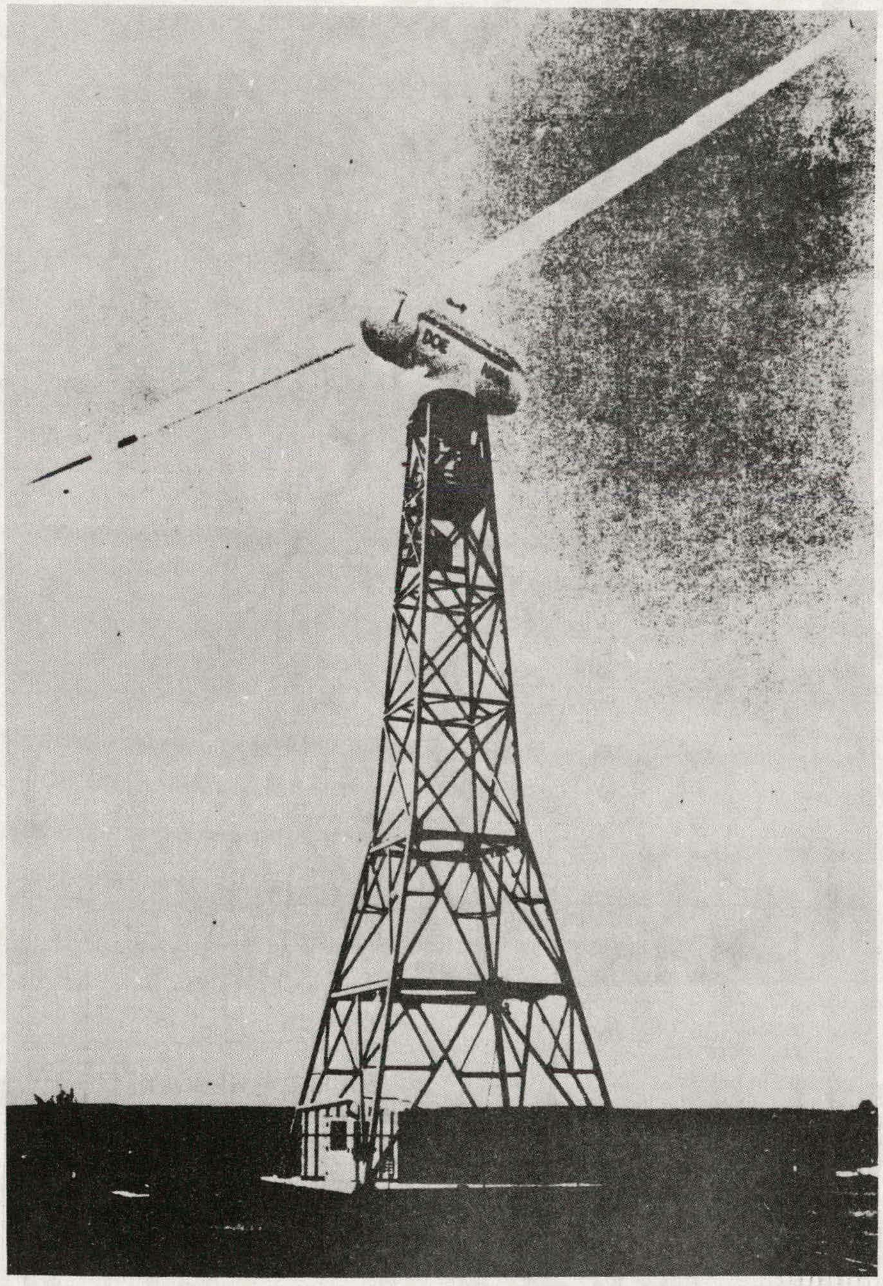


Figure 6.3 100-kilowatt wind turbine generator

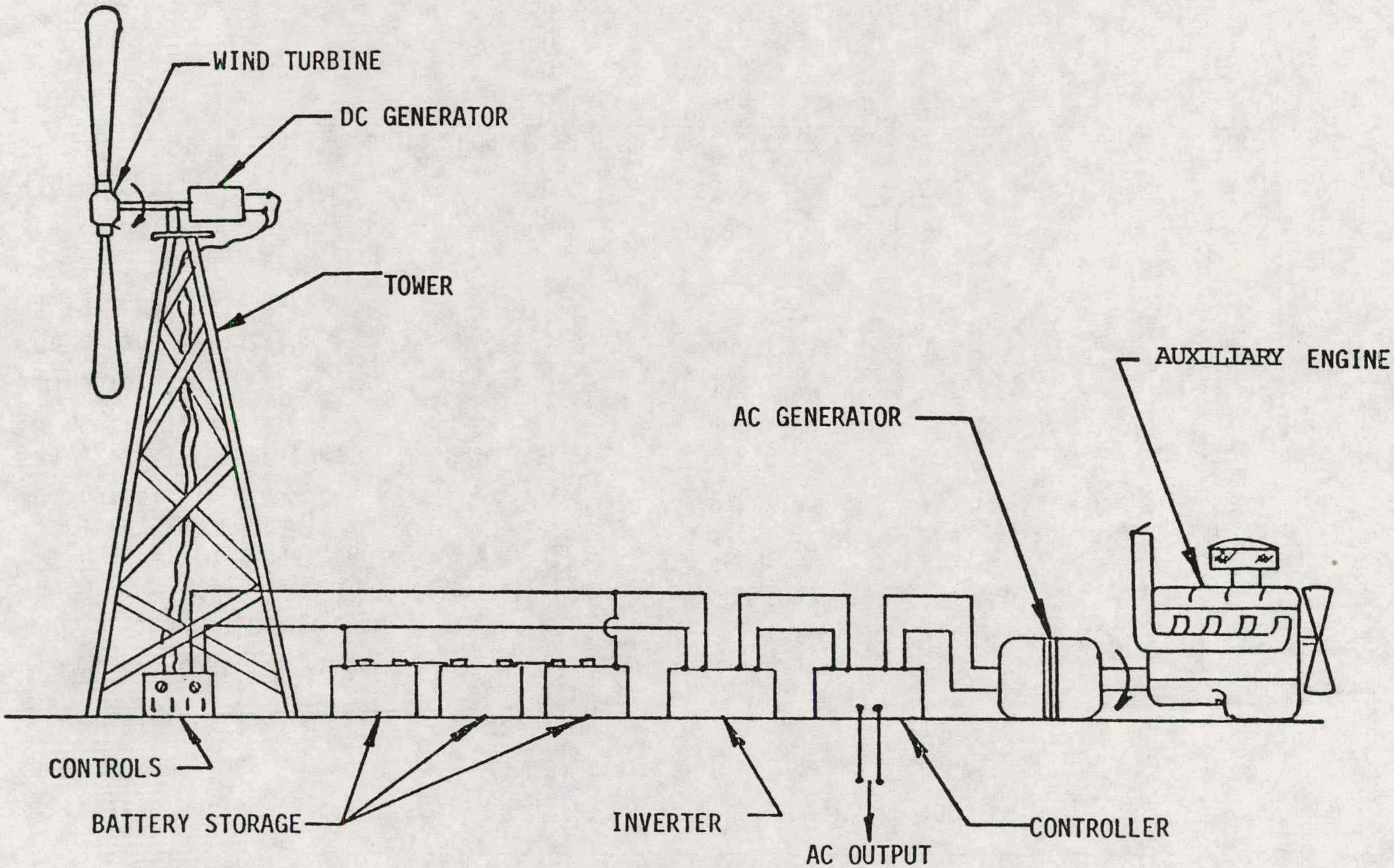


Figure 6.4 SCHEMATIC OF A WIND POWER SYSTEM

Table 6.1

COST SUMMARY FOR 3 SIZE WIND TURBINES (in $/kW in 8 m/s wind)

Nameplate Rating	6 kW	100 kW	1000 kW
Rated wind speed	13.5 m/s	8 m/s	8 m/s*
Output in 8 m/s wind	2.5 kW	100 kW	1000 kW
Component Cost for System			
Rotor (Blades, Pitch Change, Hub)	-	700 (45)**	445 (50)
Mechanical (Gear Box, Bed Plate, Yaw Control, Shafts)	-	275 (18)	190 (22)
Electrical (Generator, Controls, etc.)	-	165 (11)	70 (7)
Wind Turbine	1600	1140	705
Tower and Foundation	245	400 (26)	185 (21)
Total Equipment Costs	1845	1540	890
Transportation, Site Prep, Installation & Testing	1005	750	110
TOTAL COST	2850	2290	1000

COSTS ASSUMING PURCHASE OF BLADES, ELECTRICAL EQUIPMENT AND MATERIAL ONLY

Blades	400	350	225
Elec. & Power Conditioning	250	160	65
Steel	100	70	40
Concrete	50	30	10
TOTAL EQUIPMENT COST	800	610	340

* Measured at 15 meter height.

** Percent of total equipment costs.

are based on 4% operation and maintenance costs, 8% mortgage, and 30-year life of equipment.

Figure 6.5 indicates the cost of power for each of the three size systems of Table 6.1 for a range of average wind speeds. These costs are based on constant wind speeds and would be lower if typical variations in wind speed over the year were accounted for, since the power output of a wind turbine system is proportional to the cube of the wind velocity. Therefore, a 12.7 mph average annual wind (such as that indicated in Chiclayo and San Juan) will produce power at a somewhat lower cost than indicated in Figure 6.5. Thus, it is not unreasonable to assume that the cost of power can range from 4¢ to 12¢/kWh depending upon the system size. For rural power generation applications in Peru, these costs compare favorably to those of a small Diesel powered system. It should be re-emphasized here that all power costs and outputs are based on indications of Peru's wind regime and not on highly reliable data.

6.4 Implementation Scenario

As with photovoltaic power systems, the low cost of hydropower limits the implementation of wind turbine generators and pumps to areas remote from a grid or without mini-hydro potential. Table 6.2 describes a scenario for installing wind power systems for rural electrification and water pumping in Peru. In the 1980s, the use of small systems is increased, and by 1990, when the locations with the best wind regimes have been determined, systems of proven reliability will be installed for larger scale pumping and supplementary power for conventional fuel-fired units.

Figure 6.6 shows the nameplate capacity installed annually and the resultant total capacity of wind turbine systems installed according to the scenario. Figure 6.7 shows the total annual power output corresponding to a capacity factor of 27% for small wind machines and 32% for large machines. These capacity factors are consistent with an average wind speed of 5.7 m/s, found in several areas of Peru, and system operation for 8000 hours per year.

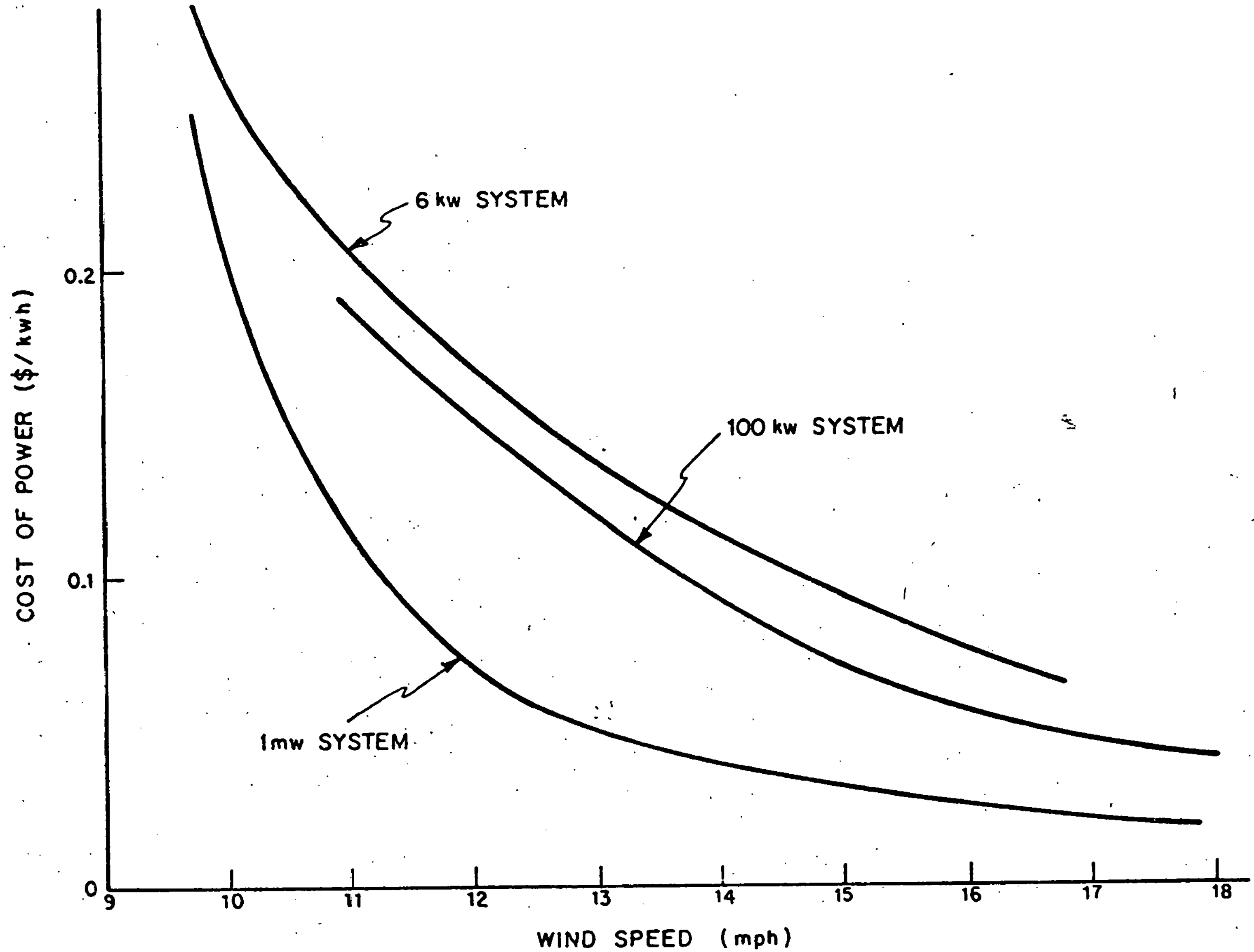


Figure 6.5 COST OF WIND GENERATORS

Table 6.2

WIND TURBINE IMPLEMENTATION SCENARIO

	NUMBER OF UNITS INSTALLED ANNUALLY	AVERAGE NAMEPLATE RATED SIZE (kW)	TOTAL NAMEPLATE CAPACITY (kW)
1980	20	10	200
	2	100	200
			400
1985	200	10	2000
	10	100	1000
			3000
1990	200	10	2000
	15	100	1500
			3500
2000	200	10	2000
	20	100	2000
			4000

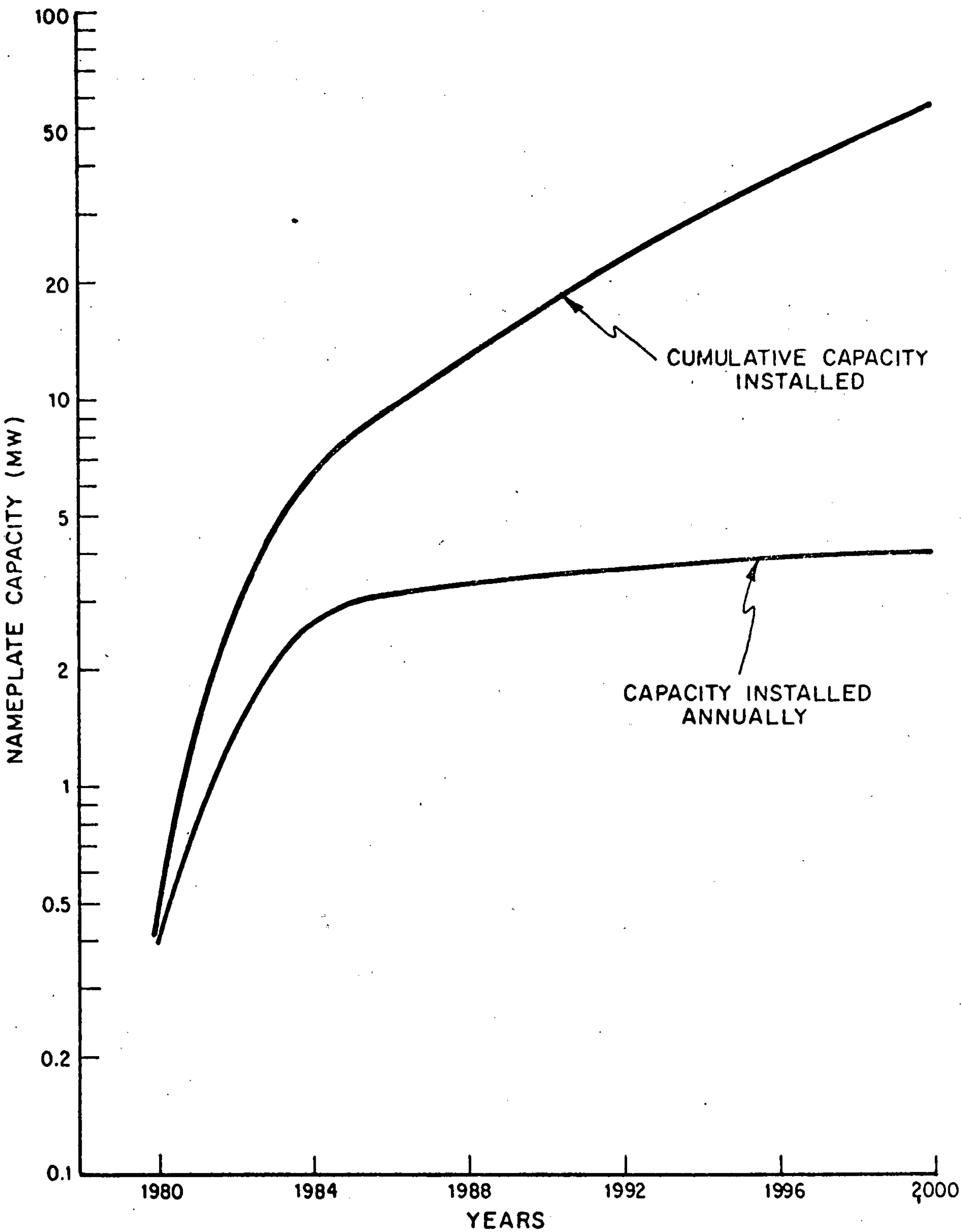


Figure 6.6 WIND POWER INSTALLATION SCENARIO

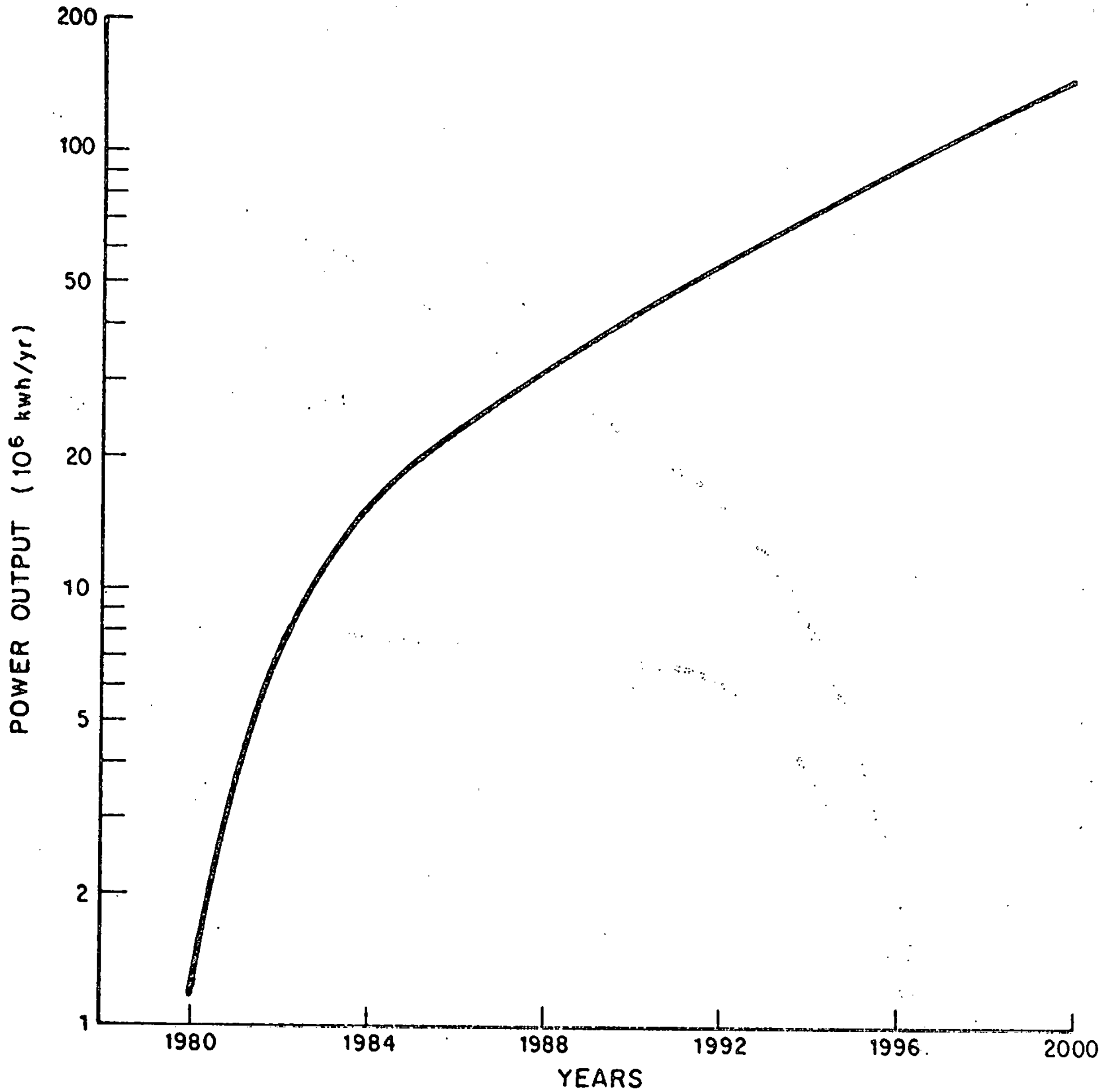


Figure 6.7 ANNUAL POWER OUTPUT FOR WIND POWER SCENARIO

6.5 Resource Requirements

The implementation scenario outlined above results in the annual resource requirements outlined in Table 6.3. This use of materials represents about 0.1% of steel and only 0.01% of cement production in 1976. The labor requirements indicated are quite modest so that labor availability will not be a constraining factor.

The operation and maintenance requirements associated with the installation scenarios are also indicated in Table 6.3. In the year 2000, about 300 people are needed to operate and take care of the country's wind turbine installations. This is a greater portion of the labor force than will be used to manufacture the wind turbines installed in that year. This is primarily due to the cumulative nature of equipment installations; i.e., equipment is only fabricated once, but it must be operated and maintained all during its useful life.

Table 6.3

RESOURCE REQUIREMENTS FOR WIND POWER INSTALLATION SCENARIO

	1985	1990	2000
	ANNUAL MATERIAL REQUIREMENTS (tons)		
Steel	290	350	400
Copper	6	7	8
Cement	180	210	240
Fiberglas & Resin	11	13	15
	ANNUAL MANPOWER REQUIREMENTS (man-years)		
Tech/Manage.	5	6	7
Manuf./Install.	110	130	150
O&M	40	90	290
	FINANCIAL REQUIREMENTS ($ X 10^6)		
Materials/Comp.	1.2	1.6	2.0
Labor	2.5	3.3	4.0
O&M	.4	.9	3.0
TOTAL	4.1	5.8	9.0

7.0 SOLAR DESALINATION

7.1 Introduction

Despite Peru's many rivers and vast hydropower potential, there is an inverse distribution between the country's water supply and population and economic centers. For example, the coastal region holds 46% of the population, but only 2.3% of Peru's water resources.

Present activity in water desalination is limited in Peru; in large part due to the relatively high cost of operating conventional desalination systems. However, in arid regions with a scarcity of fresh ground water, there could be a demand for desalination systems if the operational costs (which are heavily energy dependent) could be reduced from present levels. Any such water produced, however, would probably be only for consumption by people and livestock in areas where potable well water is not available. The potential for using desalinated water for irrigation is probably quite low due to the expected high cost of desalination (even if solar energy is used).

The distilling of sea and brackish water was one of the earliest practical applications of solar energy. A system was built in Chile in the late 1800's and systems are operating today in Greece, Mexico and Australia. There is still a great deal of interest in this subject area and one of the groups doing R&D is the ITINTEC in Peru. To date, however, solar desalination has not been used to any significant degree in Peru.

7.2 System Design

Most solar distillation units (solar stills) have utilized some form of the "humidification" process whereby solar energy passes through the glass (or plastic) cover and is absorbed by the water contained in a shallow pond (Figure 7.1). Vapor forms above the solar heated water (typically at a temperature of 45°-70°C) and condenses on the relatively cool cover plate and dribbles down to a trough and then to a collection point.

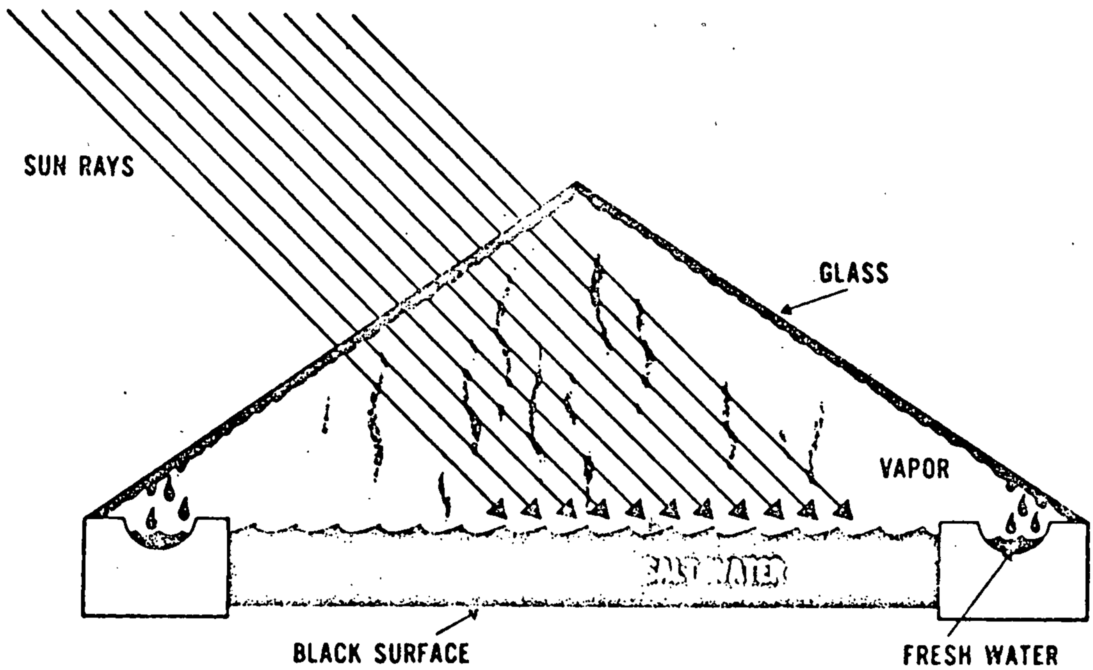


Figure 7.1 A SIMPLE SOLAR STILL

Much work has been done to lower the cost and improve the efficiency of the solar "humidification" process. The performance of this arrangement, however, is subject to two fundamental limitations;

- Each kilogram of water requires over 555 K-cal of energy input for the purification process, and
- The basic heat transfer processes are such that the thermal efficiency is in the 40%-60% range.

As a result, the humidification process requires a minimum of 0.2 square meters of collector area for each liter per day of capacity. Solar stills now in operation have capacities ranging from 400 to 28,000 liter/day. Their sized range from 100 to 8,000 square meters and average production is 2.86 liter/m^2-day.

For larger systems it may be preferable to utilize solar energy to drive more energy efficient desalination processes than the simple distillation process previously described.

One such process is multi-stage flash distillation (MSFD) as shown in Figure 7.2 coupled with a solar collector array. As a result of using multiple distillation steps, these units require only 15% to 40% of the heat input per kilogram of water desalted as do simple solar stills with corresponding decreases in collector area requirements if suitably designed collectors are used. At the relatively modest temperatures required of MSFD systems, collectors using low levels of concentration such as Compound Parabolic Concentrators, parabolic troughs, or linear Fresnel lenses could be used. Capacities of multi-stage flash distillation units run from $.004 \times 10^6$ to 4×10^6 liter/day.

In another process, vapor compression, water vapor is compressed adiabatically causing a temperature rise in the vapor, which provides heat for distillation of incoming seawater, and the vapor in turn condenses to produce fresh water.

There is also the reverse osmosis process where one side of a membrane (typically cellulose acetate) is supplied with saline water at

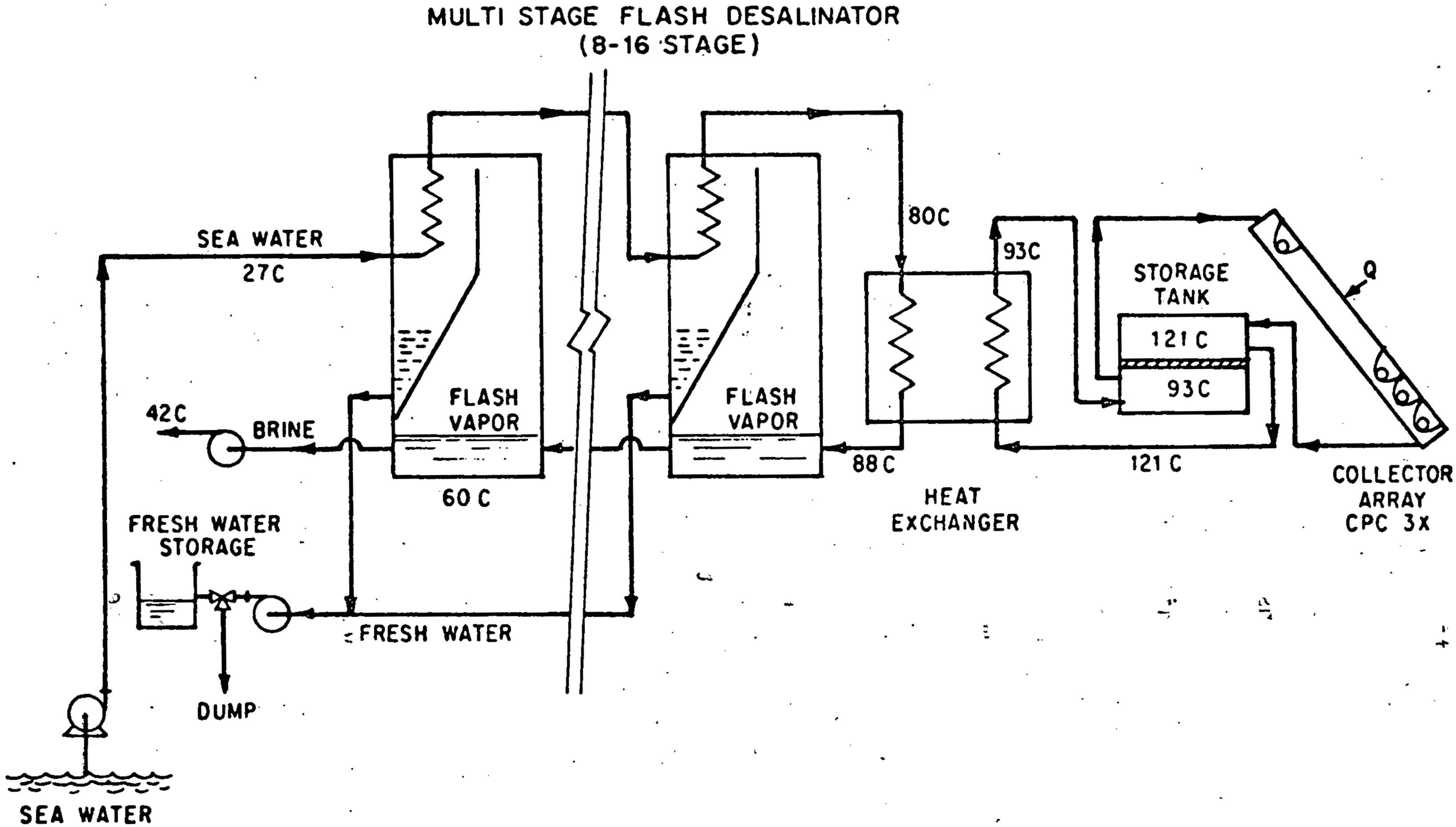


Figure 7.2 MULTI-STAGE FLASH DISTILLATION (MSFD) - SOLAR

a high pressure (14-105 kg/cm^2) and these semi-permeable membranes preferentially diffuse pure water leaving the strong brine behind. The pressure difference required across the membranes increases with the degree of salinity which is one reason why reverse osmosis systems are usually used with brackish water with salt levels well below that of ocean water such as that often found in desert wells.

Both vapor compression and reverse osmosis systems require power input for their operation which could be supplied by solar thermal power units, photovoltaic generators, or wind turbine systems. Typical size range for these type of units are .02 to 4 X 10^6 liter/day.

7.3 Cost Estimates and Economics

According to a Bechtel report,* the actual cost of solar stills in the 1960s varied from about \$20/m^2 in developing countries to \$29/m^2 in industrial countries and at present these costs are estimated to be in the range of \$32 to \$60 per square meter of collector area. Based on the lower end of this cost range the resultant cost of water from solar stills is estimated to be about \$2.91 per 1000 liters (\$11.02/1000 gallons) assuming a useful life of 20 years and an interest rate of 8%.

The cost of water from solar "fired" multi-stage flash distillation systems is shown in Figure 7.3 as a function of capacity. This analysis assumes MSFD and 5X CPC collector costs. As indicated, the MSFD units are more economical in the larger sizes due primarily to the energy efficiency associated with multiple stages of evaporation as compared to a single evaporation process in a solar still.

The cost of water from the solar fired MSFD unit are about the same as from an oil fired system with an oil cost of 10¢/liter (or 40¢/gallon, about world oil prices). The economic advantages of the solar fired systems should, therefore, increase with time as fuel prices increase - particularly in remote regions where fuel transportation costs must also be considered.

* "Technical and Economic Assessment of Solar Distillation for Large Scale Production of Fresh Water," Bechtel Corp, December, 1977.

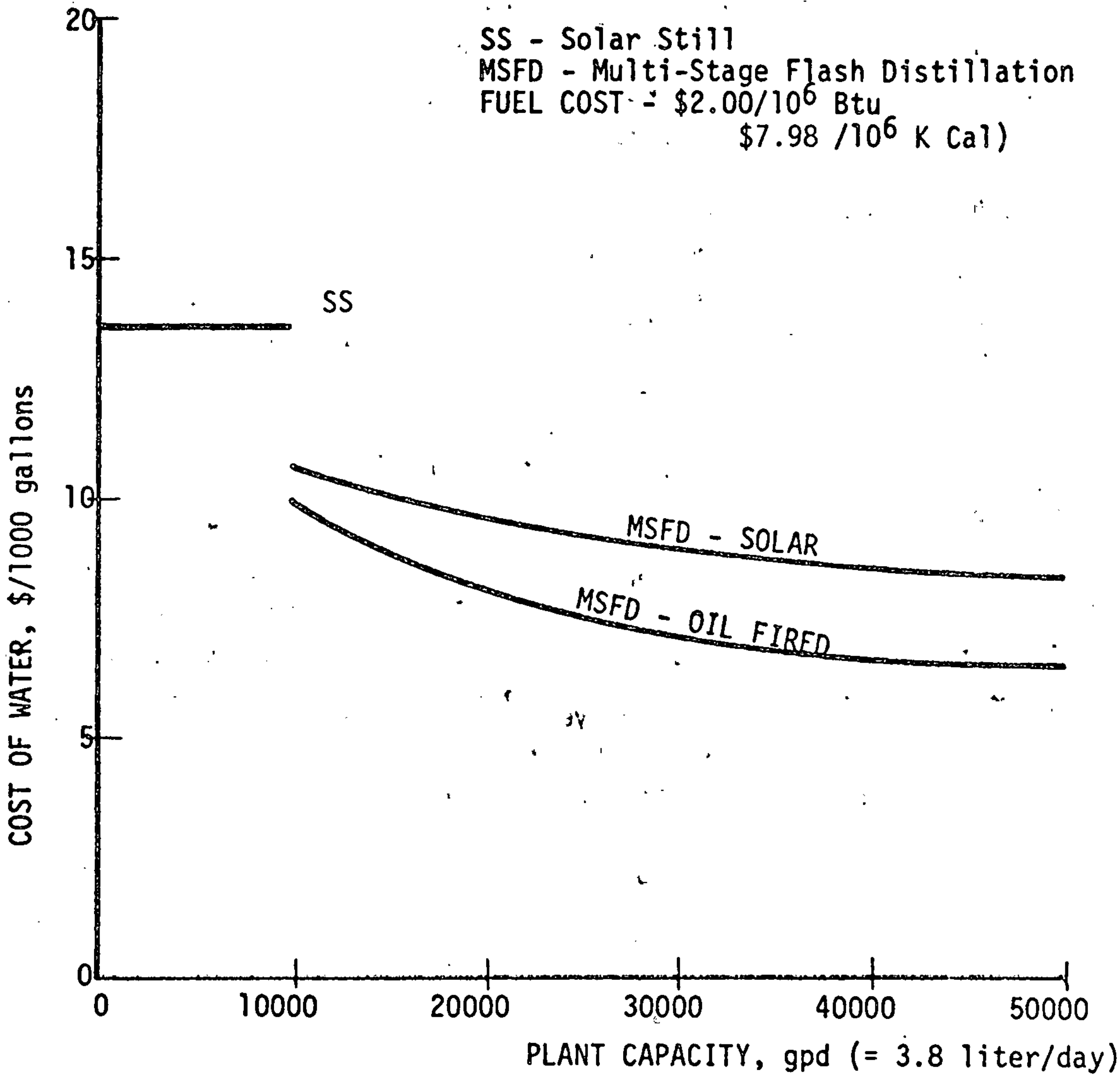


Figure 7.3 COST OF PRODUCT WATER

Most of the cost figures used in the above study were obtained for the preliminary assessment so that no rigorous optimization of cost of sophisticated analysis in economics were performed. It is believed that for MSFD-solar, labor cost is approximately 50% of the total. Should Peru fabricate some portions of the solar collectors and the storage tanks, the cost due to labor will be greatly reduced, as will the cost of water produced by MSFD-solar.

The cost of water from solar or wind operated reverse osmosis and vapor compression units should also be established so that the most economical approaches for producing fresh water can be identified for a variety of sizes, locations, and water characteristics.

7.4 Conclusions

Since the cost of these solar desalination systems is not expected to change greatly, their use is not usually economically feasible where conventional distillation systems are not already being considered. The rising cost of fossil fuels, however, makes solar distillation competitive with conventionally operated systems in the time frame under consideration. The most likely application for desalination systems is in areas where potable water must be carried in (with resultant high water costs) and/or where the potable well water is unavailable at reasonable cost.

8.0 SOLAR AIR CONDITIONING AND REFRIGERATION

8.1 Background

Using solar energy for air conditioning has generally been considered an attractive application due, in part, to the tendency for high air conditioning load to occur under conditions of high solar flux. The equipment used to provide air conditioning is often similar to that required for refrigeration (both chilling of fresh foods and freezing) so that developing solar air conditioning capability leads to a solar refrigeration capability (and vice versa).

Presently, neither air conditioning nor warehouse refrigeration are large energy users in Peru. This situation will probably change to some degree as living standards increase and the use of food preservation facilities to reduce storage and transportation losses become more widespread. However, the very small current demand does not warrant large implementation outlines for the near future.

As indicated below, solar cooling is basically a special application of one of the solar power or heating options discussed in previous sections. This application is, however, discussed as a separate issue due both to the special interest consistently shown in this subject and its special characteristics which benefit economic performance.

8.2 Description of System Options

There are a number of approaches for providing a cooling effect with solar energy. These include;

- Production of power via a solar power arrangement and operation of vapor compression units. In this arrangement, shaft power may be directly coupled to a compressor (Figure 8.1) or electricity can be generated which drives a motor operated compressor (Figure 8.2),
- Use of solar heat to operate absorption cooling units, and
- Use of evaporative cooling arrangements.

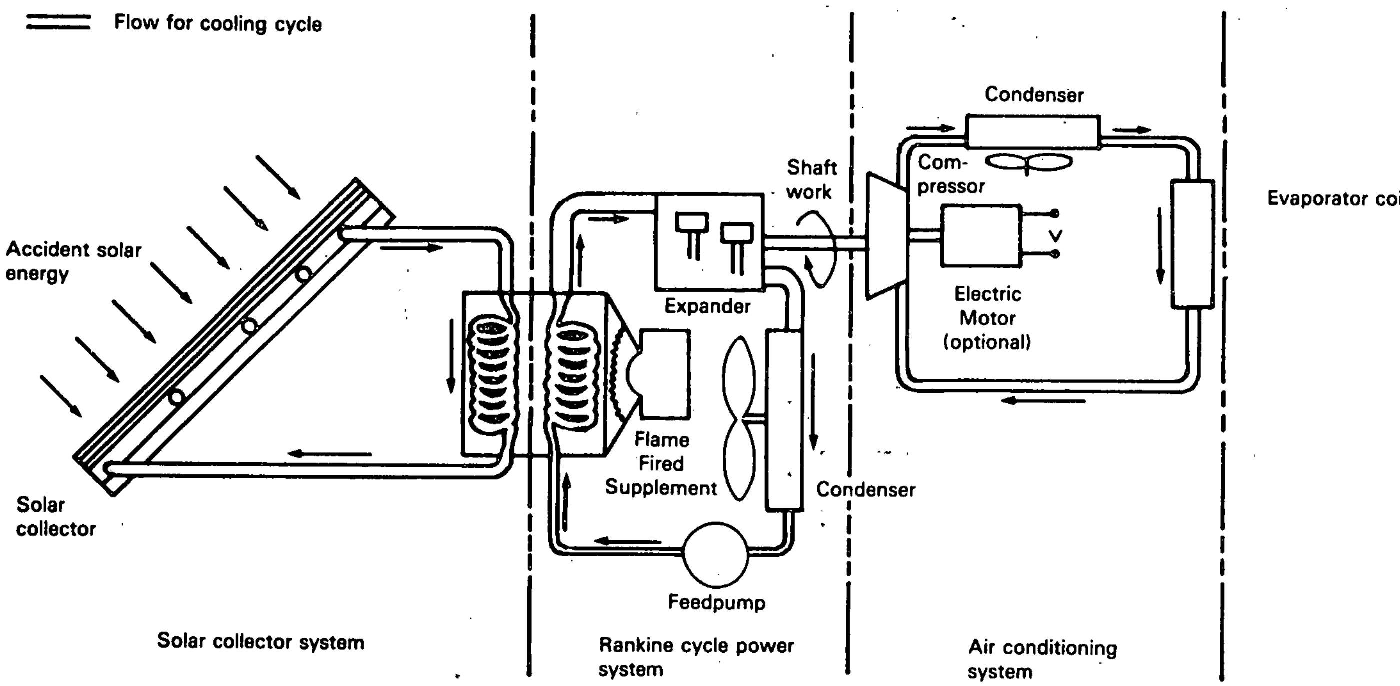


Figure 8.1 SCHEMATIC OF A RANKINE CYCLE ENGINE POWERED COOLING SYSTEM USING A SOLAR ENERGY HEAT SOURCE

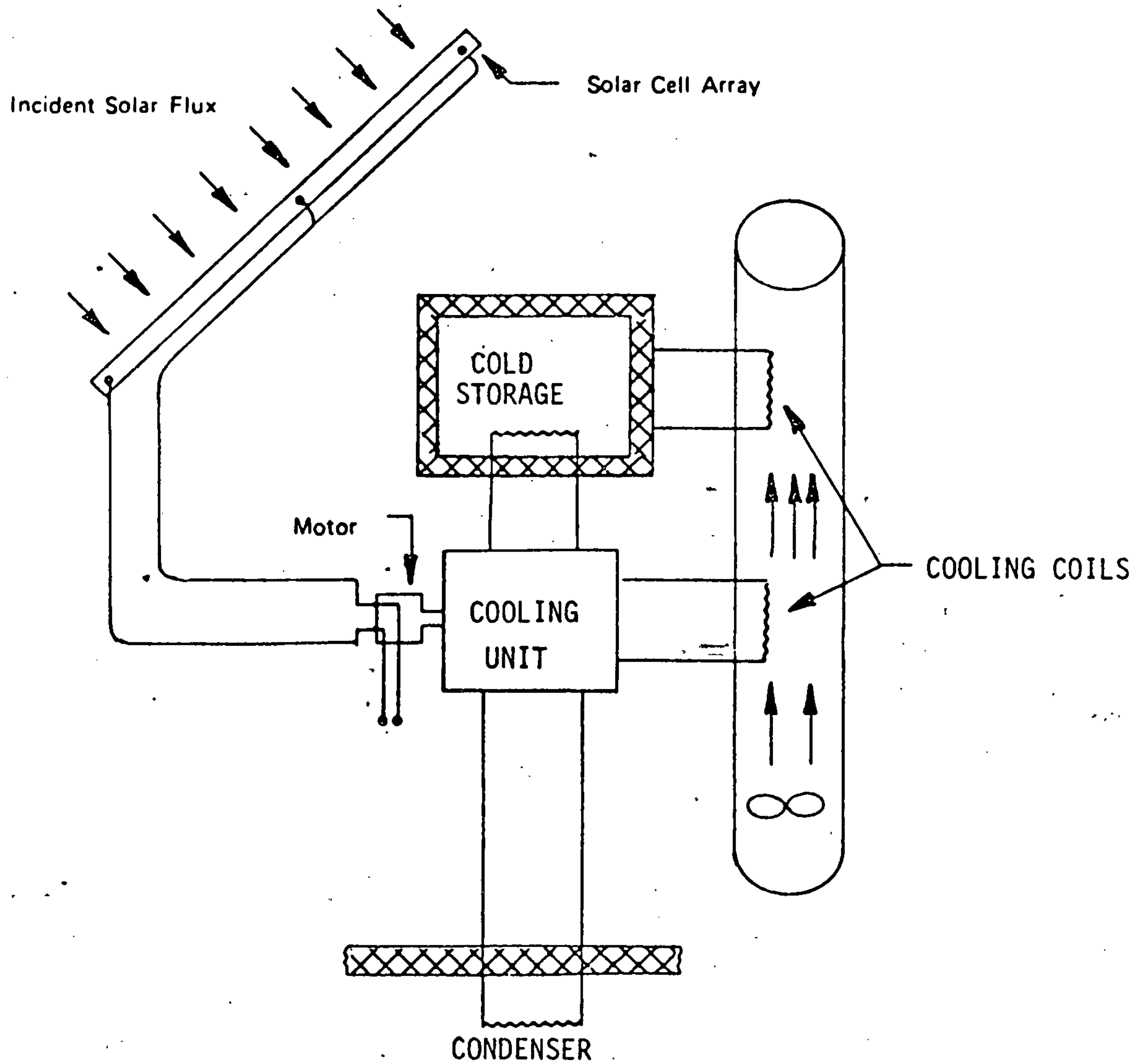


Figure 8.2 SOLAR CELL POWERED COOLING SYSTEM

The latter arrangement is commonly used in arid regions with low humidity to provide some degree of cooling for small buildings. As such, it may be appropriate for use in many parts of Peru. However, only the first two arrangements are amenable to provide cooling for large building units (which are more likely to be air conditioned) or to provide sufficiently low temperatures for refrigeration applications.

Both Figure 8.1 and Figure 8.2 indicate a "cold storage" volume which would usually be chilled water. This is an important advantage of solar cooling systems where power is produced to operate vapor compression units. The ability to store in the form of chilled water eliminates the need for more costly battery storage units which favor this application over power generation applications in general.

8.3 System Costs and Economics

Solar Driven Vapor Compression:

Those systems which use solar energy to power conventional vapor compression units have the same basic economics as the solar thermal, photovoltaic, and wind turbine generator arrangements discussed in Sections 4.0, 5.0, and 6.0. That is, the economics of the solar power generation options is unaffected by the end use of the power except to the degree that the need for storage or other auxiliary equipment (inverters, switchgear, etc.) can be reduced. The economic analysis of the technology sections all assumed that attractive applications (such as solar cooling) were stressed so that the need for auxiliary equipment was minimized.

As indicated in these sections, even the near-term solar power systems could be used to operate conventional cooling units in remote areas at a lower cost than Diesel generators. This makes an attractive early application of solar power for remote hotels, clinics, cold storage facilities, etc.

Solar Operated Absorption System:

Solar derived heat can also be used to directly operate absorption air conditioning systems; particularly those using lithium-bromide as the working fluid. Commercially available equipment can operate effectively (COP $\approx$ 0.5 - 0.6) with heat input temperatures in the 190° - 220°F range. These temperatures cannot be efficiently and reliably attained with the simple flat plate collectors normally used for water heating. However, either flat plate collectors of advanced design (good selective coatings, high transmission covers, evacuated tubes, etc.) or those using some degree of solar concentration (linear Fresnel lenses, parabolic troughs, etc.) can effectively operate at the required temperatures. Over 20 systems using solar driven absorption units have been built and operated in the United States, thereby demonstrating this approach to solar air conditioning.

A solar operated absorption cooling system is basically a solar hot water system "firing" a commercial lithium-bromide absorption unit. The absorption unit could also be operated with a gas or oil fired burner. As such, the economics of the solar fired unit is indicated by the cost of solar heat as compared to supplying heat by conventional sources.

The collector configurations which can supply heat at the required temperature level are usually more costly than simple water heaters. Manufacturers of high performance collectors project a production cost of about $108 per square meter. The resultant installed system cost for a hot water delivery system capable of operating absorption cooling systems would be about $150 to $180 per square meter. Based on a 20-year life, an interest rate of 8% and a 2% O&M charge, the cost of heat delivered by the high temperature solar water system (to drive the absorption unit) would be about $8 per 10^9 joules. By comparison the cost of delivered heat from 10¢/liter oil (approximate world price) would be about $5.50 per 10^9 joules. The cost of solar driven absorption units, therefore, approaches being competitive with fuel operated systems with the breakeven cost being about 15¢/liter. This fuel cost is probably applicable to

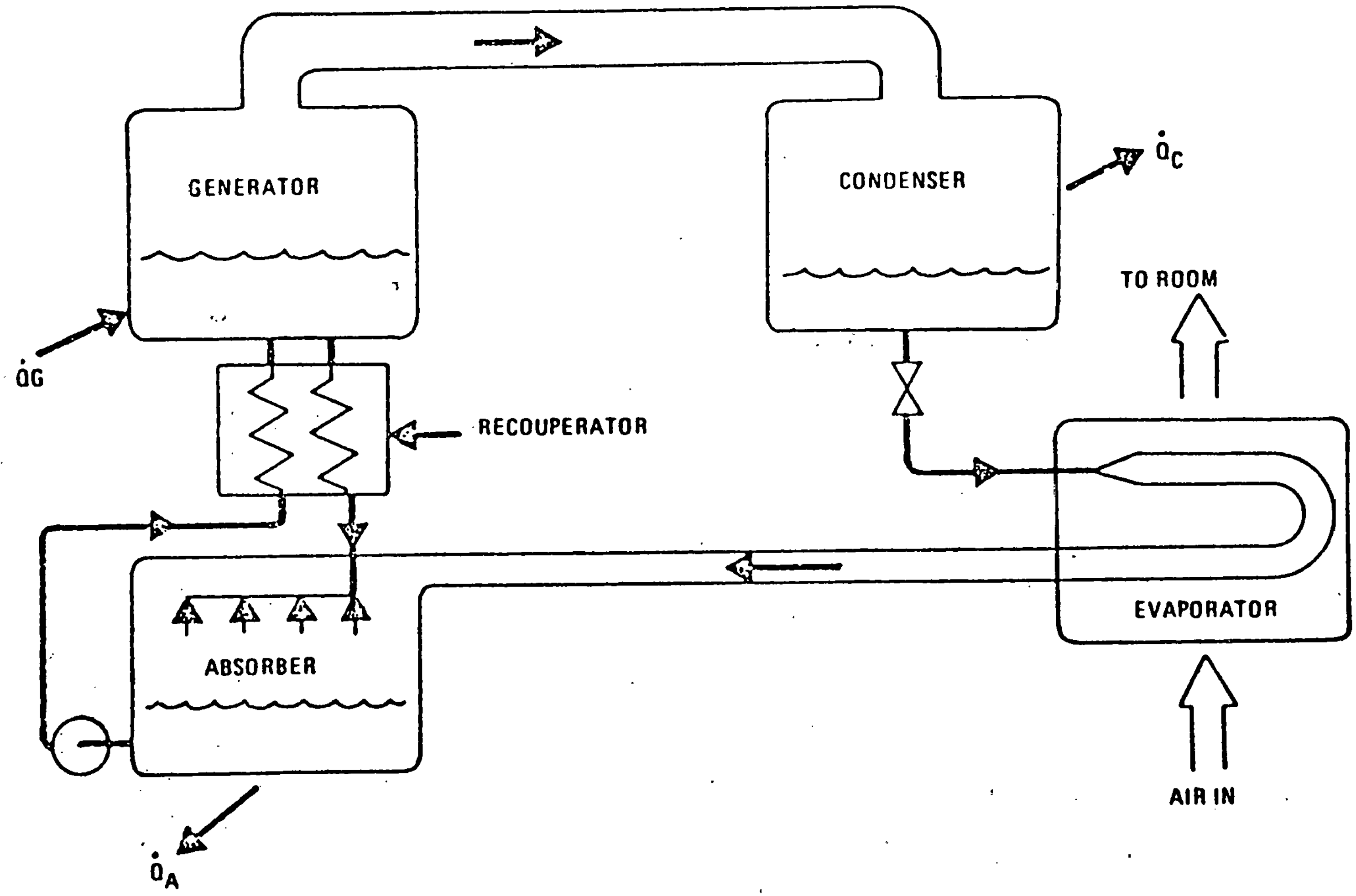


Figure 8.3 ABSORPTION SYSTEM SCHEMATIC

remote areas when the costs of transportation and storage are considered.

As with the solar heating systems of Section 3.2, most of the solar collector configurations could be made in Peru further improving the economics of solar cooling.

8.4 Comparison of Options

The solar driven vapor compression units offer a higher degree of feasibility than the absorption systems since any form of solar power (photovoltaics, wind generators, etc.) can be used for their operation. The performance of solar driven absorption units, on the other hand, is presently better demonstrated than the other solar options. The economics of this arrangement, therefore, are better defined than systems such as photovoltaics which require significant cost reductions in order to be practical. Drawbacks to the absorption units, however, include;

- Their relatively limited use and resultant lack of in-country personnel experienced with their operation, and
- The requirement for a cooling tower which for reliable operation could be a significant problem in Peru due to lack of water and/or high maintenance requirements.

8.5 Conclusions

Presently food preservation facilities in Peru are in very limited use which leads to significant spoilage. Furthermore, the need for food preservation can be particularly acute in remote regions where rapid access to transportation, either to export or import food, is limited. In the near-term solar refrigeration could, therefore, provide much needed cold storage facilities in remote regions of Peru thereby improving productivity in these areas where the government hopes to stabilize the population.

Appendix A

COST OF POWER FROM DIESEL ENGINES

Where the need for small-scale power generation has arisen in the past, the conventional mode has been to install a small fuel-fired engine generator or pump, generally a Diesel engine. It is with these technologically advanced engines that renewable power generating systems (photovoltaics, solar thermal, biomass, and wind turbines) compete in a 1980s time frame, when the price of fossil fuels rises and the cost of these new technologies falls. It would therefore be instructive to examine the costs of power associated with Diesel engine generators for comparison to the costs of renewable energy generators.

The installed cost of engine powered generating systems is a function of the system's location, application and size. A Diesel electric generator with backup in a very remote area, for example, requires fuel storage, circuit breakers, relays, and a protective building which can more than double the installed system cost over the generator cost. Alternatively, a simple water pump can operate in the open without most of the ancillary equipment listed above.

The cost of power from Diesel power units is a function of many other variables such as fuel efficiency, fuel cost, useful life, and maintenance costs. For purposes of this analysis it was assumed that;

- Engine costs range from $700/kW for very small systems to less than $300/kW for very large systems,
- Engine costs have been multiplied by an average factor of 1.5 to account for installation and subordinate equipment,
- The engine runs at a 33% capacity factor (equivalent to full capacity operation for 8 hours/day),
- A major overhaul is needed every 5000 hours with costs at 30% of initial engine cost,
- Resultant engine life is 10 years,

- Engine efficiency is 25% for smaller units and 30% for the very large units,
- Diesel fuel has a heat content of 140,000 Btu/gal, and
- There is an 8% interest rate on borrowed money.

Figure A.1 shows the cost of power vs Diesel generator size for three Diesel fuel costs. The $.50/gallon figure is consistent with the world market cost of fuel, and $1.20/gallon is presently appropriate to remote areas where the transportation costs become significant, and in a future time frame will be appropriate to world market oil prices.

For many remote areas in Peru, a delivered fuel cost of $.80/gallon may be more applicable. The associated cost power for a small pumping or electricity generating system (10 kW) is about 14¢ to 18¢/kWh. Power from larger Diesel generators and pumps cost about 10¢ to 12¢/kWh with current fuel prices, but can be expected to rise with the cost of fossil fuel, so that these prices can be considered the bottom line for future installations. For very large systems in the MW range (used in some larger towns, mines, and industrial complexes) the cost of power reduces to about 8¢ or 9¢/kWh. Other considerations associated with fuel-fired engine generators is their high emission levels, noise, and high maintenance requirements.

It should be noted that the power costs of Figure A.1 are relatively optimistic. Significantly higher costs than those indicated are often experienced in remote areas where maintenance of systems is poor and skilled repair personnel are not readily available.

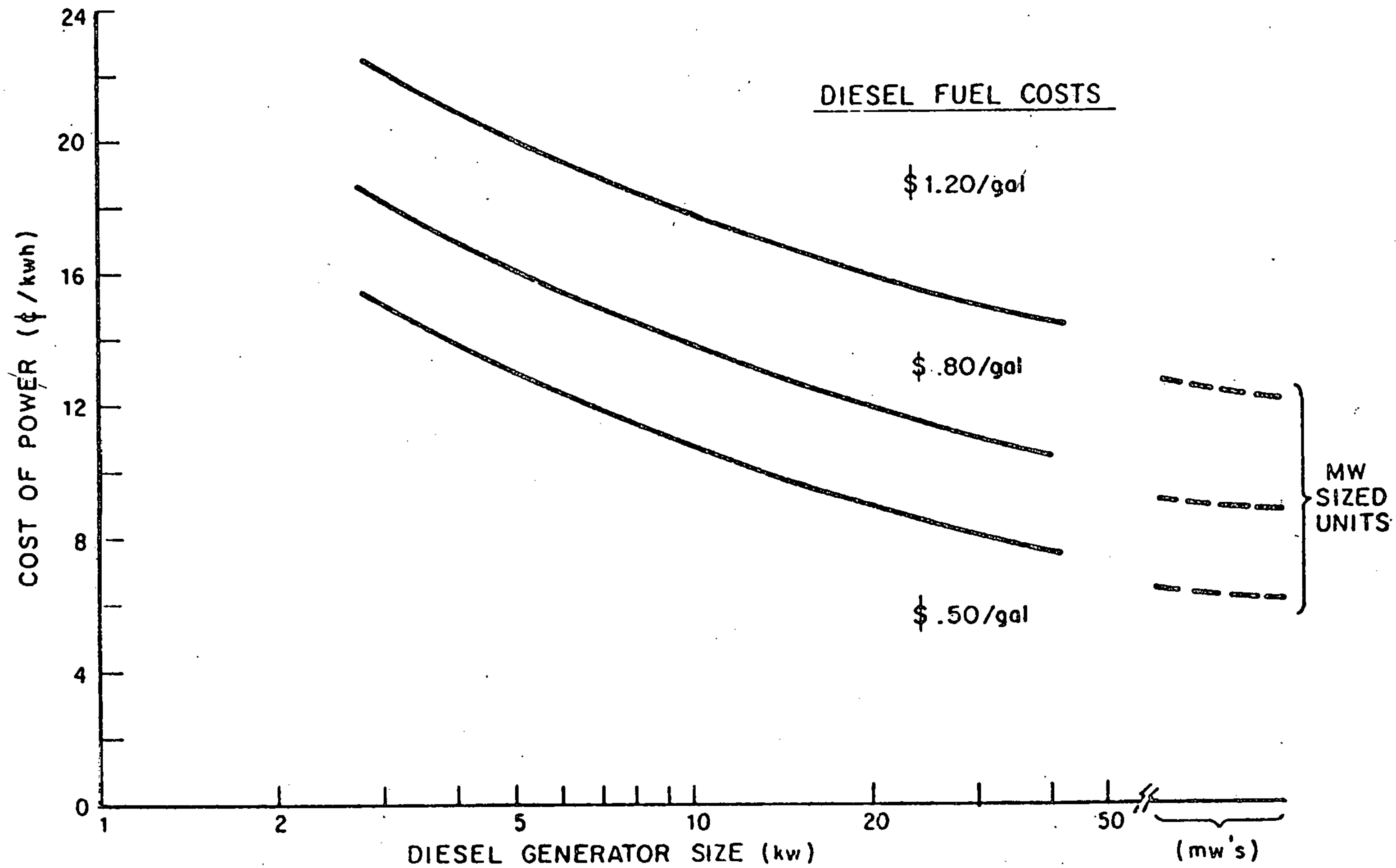


Figure A.1 COST OF POWER FROM DIESEL GENERATORS

*U.S. GOVERNMENT PRINTING OFFICE : 1980 O-620-309/2612

ANNEX - 7

POTENTIAL USE OF SOLAR/WIND ENERGY RESOURCES IN PERU

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U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

NOVEMBER, 1978

POTENTIAL USE OF SOLAR/WIND ENERGY RESOURCES IN PERU

PREPARED IN SUPPORT OF THE PERU ENERGY ASSESSMENT STUDY

November, 1978

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ACKNOWLEDGEMENTS

This report was prepared with inputs from other members of the United States Energy Team, in particular, Dr. Eric Farber of The University of Florida who provided valuable insights on potential applications and Dr. Eldon Boes of Sandia Laboratories who had primary responsibility for collecting and interpreting the available solar/wind data.

1.0 INTRODUCTION AND SUMMARY

1.1 Advantages of Solar Utilization

The renewable resources addressed in this section include direct solar energy and wind power.*

Despite its proximity to the equator, the solar availability in Peru is quite variable. Very high insolation levels are predominant in some coastal and Sierra regions (Piura, Arequipa, etc.); however, the highly populous Lima region (with 25% of the population) is subject to a persistent (but somewhat localized) cloud cover for about half the year which reduces solar availability in this region to about 1580 kWh/year-m^2 (.5 X 10^6 Btu/year-ft^2) (about that in the northeastern United States). Although wind availability is not well-defined, it appears that some coastal regions such as Piura, Paracas, etc., have average wind velocities consistent with effective operation of wind turbines.**

Several factors, combined with renewable good resource availability could make the use of solar/wind energy systems in Peru particularly attractive. These factors are discussed below.

Rural Development:

Peru is a large country with over 3,000 villages scattered throughout the country. Consequently, only about 30% of the population has access to electricity. Furthermore, the rough terrain and dispersed loads make it unlikely that substantial electrification of rural areas will occur by normal extension of the utility grid.

Solar power generation is ideally suited for use in relatively small increments in distributed power systems. The near-term use of solar power, therefore, is considered within the context of a need for rural electrification which could relieve pressure on fossil fuel fired systems and on the need to extend the utility grid to service uneconomical loads.

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* Biomass is discussed in another section of the report.

** As evidenced by the present use of wind pumps in these areas.

Rural Migration:

One of the most pressing social/economic problems facing Peru is the migration of rural residents to the urban areas, and in particular to Lima. There are also energy implications associated with this migration since urban residents use much more energy for utilities and transportation than do rural residents. It is expected that modest improvements in living standards that would result from supplying electricity and hot water to rural residents might reduce the rural to urban migration with resultant benefits far in excess of the energy actually provided.

In-Country Manufacture:

For the most part, both solar heating and solar power systems could be manufactured in Peru using indigenous labor and material resources. Manufacture in Peru has the advantage of reducing the foreign exchange component of developing energy resources. Possibly of equal importance would be the positive social/economic benefits resulting from building up an in-country capability in a growing technology field which can help create a job producing industrial base both for internal and export markets.

Technical Status:

Several of the solar technologies considered are already quite well developed. Combined with the incremental nature of most solar related systems, this would allow Peru to initiate a solar development plan with a minimum time delay and modest front load capital requirements.

The above factors could provide an incentive for Peru to consider strongly supporting the widespread use of solar energy in appropriate applications.

Somewhat counteracting the above factors favorable to solar utilization in Peru is the fact that Peru has many non-solar energy alternatives available. For example, it appears that many of the remote villages in the Sierra region could be provided with power by means of mini-hydro systems which would usually have better economic performance than solar/wind systems. Also, about 74% of the electric power is now produced by large scale hydro facilities which make it unlikely that solar/wind sources will become grid connected during the time frame of interest.

The scenarios developed in this report, therefore, assumes that solar/wind power systems are used primarily to;

- Provide small scale electrification to rural villages which do not have a viable mini-hydro resource and are too remote from the grid to justify a grid extension, and
- Replace and/or supplement power produced by Diesel (or oil fired steam) power systems in those regions remote from the grid serviced by hydro facilities. Such applications are assumed to come on line in the post 1985 time period when the economics of solar/wind power units have been demonstrated.

As indicated later, the resultant impact potential of solar/wind power systems is quite limited.

1.2 Solar Technologies Considered

The renewable energy resources stressed in this assignment were;

- Solar Water Heating
- Solar Electric Power Generation
  - Solar Thermal
  - Photovoltaics
- Wind Power Generation

A brief summary of the status of the technology options and their applicability in Peru is given below.

Solar Water Heating:

Solar water heating is a well-demonstrated technology which already has widespread application on a worldwide basis. These systems could be installed on residential, institutional, and commercial buildings in Peru resulting in reductions in the use of bottled gas, electricity and kerosene now used for water heating applications.

It should be noted, however, that water heating in residences is still considered a luxury in Peru and that the introduction of solar water heaters will often show up as an increase in energy demand rather than as a substitute for conventional energy sources.

Solar Power Generation:

The operation of small scale (1-50 kW) solar thermal power units has been demonstrated by a number of units fabricated in France, the United States and Germany. These systems usually operate at modest temperature levels of 180°-300°F and convert heat generated by flat plate or trough collectors into power by means of specially designed heat engines.* The most common application for these smaller power units has been for water pumping which is also of primary concern in Peru.

There are extensive industrial and government sponsored programs to improve the technical/economic performance of these systems so they are more competitive with conventional power sources; particularly Diesel engines which are often used in remote areas for power production.

The major effort in large scale solar power generation is directed toward the central receiver concept whereby an array of mirrors redirect solar energy to a boiler placed on a tower. Initial testing of major subsystems associated with this concept has been initiated and a 10 MW power plant is scheduled to begin operation in 1981 at Barstow, California. If successful, large power units based on this concept could be commercially available by the late 1980s.

Photovoltaic power units, which directly convert solar energy to electricity with no moving parts, are presently in widespread use throughout the world to supply small amounts of power to such applications as remotely located communications equipment. The performance of these systems is well-demonstrated and present efforts are directed primarily toward lowering their cost so they are competitive with conventional power systems. The large developmental effort in this field by major companies

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* Organic Rankine cycle engines which use highly volatile refrigeration fluids.

increases the probability that substantial cost reductions in photovoltaic solar cell power units will occur so that their widespread use in the 1980s particularly for use in remote areas not serviced by the utility grid, can be justified.

Wind Power Generation:

The performance and reliability of small wind power units for electric power and water pumping has been well-demonstrated and over 10 firms in the United States, Europe, and Australia manufacture systems in the 1 kW to 25 kW range.* These systems are readily available for use in Peru in remote areas.

Large wind power systems with rated outputs of 100 kW to 4 MW are now under development and several systems with 100-200 kW capacity are undergoing performance testing in the United States. The technology of wind power systems is relatively straightforward so that the goal of having large systems readily available by the early to mid 1980s should be attained.

The advanced state of development of both large and small wind power units and the favorable wind regimes which appear to occur in some coastal areas could lead to a significant role for wind power in Peru.

Solar crop drying, air conditioning, and desalination were also considered as part of this study. Analysis of these applications indicated, however, that there was no widespread need for these functions and, therefore, their implementation would probably not have a significant impact.

1.3 Impact Summary

Tables 1.1 and 1.2 summarize the potential energy impact of solar technologies in Peru through the year 2000. The implementation rates of various solar technologies required to achieve the impacts of Tables 1.1 and 1.2 are discussed in the individual technology sections of Sections 3.0-6.0.

* Small wind powered water pumps are, in fact, now used in Peru in several windy coastal areas such as Piura.

Table 1.1

ELECTRIC POWER GENERATION IMPACTS OF RENEWABLE RESOURCES

	1985	2000
Photovoltaics		
Total Installed Capacity, MW[1]	2.3	59
Annual Power Output, JQ (10^6 kWhr)[2]	0.017 (4.7)	0.45 (120)
Wind Power		
Total Installed Capacity, MW[3]	6.5	50
Annual Power Output, JQ (10^6 kWhr)[4]	0.068 (19)	.52 (150)

1. Capacity at Peak Solar Flux
2. Assumes 0.25 Capacity Factor
3. Capacity in an 8 M/S Wind
4. Assumes 0.33 Capacity Factor

1 JQ = 10^{15} Joules

Table 1.2

SOLAR WATER HEATING IMPACT

	1985	2000
Total Installed Area, 10^6 Square Meters	0.20	0.23
Annual Heat Delivered, JQ	0.068	0.75

The scenario indicated assumes that the beneficial social and foreign exchange factors associated with solar options induces the government to actively pursue a solar policy (via low cost financing, requirements for solar in new construction, etc.). In this scenario, solar/wind power generation would contribute about 270 X 10^6 kWh (1 JQ) of electricity (or shaft power equivalent) in the year 2000. This represents about 1% of projected electricity demand at this time. The solar option is seen, therefore, to have only a modest impact on overall electricity energy use. However, the solar options are assumed to be implemented primarily in rural areas where the impact of small amounts of power could be quite large. Also, the larger power generation units would tend to provide power which would often be supplied by Diesel driven generators or pumps. As such, the electricity generated by solar will tend to displace oil which has beneficial foreign exchange ramifications.

The water heating impact indicated is equivalent to about .06% (about .75 JQ) of Peru's projected energy use in the year 2000. This impact assumes that about 100,000 residential units are installed by the year 2000. It is expected that about half of the solar contribution will essentially be an increase in demand since hot water is presently not a large energy consumer in Peru. The remaining 50% is assumed to displace bottled gas and electricity which are increasingly being used in hot water systems.

The cost of solar heating and power units is expected to decrease as a result of continuing R&D efforts and larger production volumes. The rate and extent of cost reductions will, however, depend on the present development status of the technologies. For example, the unit cost of solar hot water systems were assumed to average about \$10/ft^2 (installed) and only limited further cost reductions were expected in the future since the technologies required are well-developed.

The average unit installed cost of the solar power generating options decreases from about \$1400 per kW in 1985 to \$1100 per kW in 2000. The average capacity factor for the generating mix of direct solar and wind is about 0.3.

The relatively modest decrease in unit cost is due primarily to two factors; (1) the technologies considered will already be quite well-developed by 1985 (i.e., the major cost reductions will occur before that time), and (2) a large portion of system costs is associated with conventional equipment, each as light steel support structures, piping, systems, etc., for which the cost reduction opportunities are limited. The installed system costs are over 50% labor related and many of the materials required are produced in Peru. Therefore, the foreign exchange value of system costs is considerably less than that indicated above.

The costs indicated above were considered to justify the indicated use of solar options in Peru; particularly if the favorable foreign exchange aspects of solar are considered.

1.4 Resource Requirements

Each of the solar options can be accomplished with a variety of system options each of which would have differing requirements for manpower, finances, and materials. The baseline options selected in the technology sections, however, were considered to be consistent with Peru's resources in the above areas. The resource requirements of these options are, therefore, probably indicative of those of most systems which would be installed in Peru.

Resource requirements to implement the options leading to the energy savings of Tables 1.1 and 1.2 are indicated in Table 1.3. Solar related energy systems are fabricated primarily from basic construction materials such as steel, cement, glass, and copper all of which are manufactured in Peru.

The financial requirements indicated in Table 1.3 are broken down between materials/components and labor to indicate foreign exchange implications. Total annual outlays for manufacturing and installation increase to $6.5 million in 1985 and $14.2 million by the year 2000 with roughly 50% of outlays being labor associated directly with the fabrication and installation of solar related systems. Additional labor inputs are associated indirectly with solar applications by virtue of in-country

Table 1.3

RESOURCE REQUIREMENTS FOR RENEWABLE ENERGY IMPLEMENTATION SCENARIOS

	1985	1990	2000
	ANNUAL MATERIAL REQUIREMENTS (tons)		
Steel	740	1220	1990
Glass	260	550	1040
Aluminum	70	200	450
Cement	380	830	1600
Copper	120	150	210
Fiberglas & Resin (including insulation)	60	65	75
	ANNUAL FINANCIAL REQUIREMENTS ($ X 10^6)		
Materials/Comp.	2.7	4.3	6.9
Labor	3.8	5.3	7.3
O&M	.9	1.2	4.2
TOTAL	7.4	10.8	18.4
	LABOR REQUIREMENTS (person-yrs)		
Tech/Manage.	19	27	44
Manuf./Install.	230	330	470
O&M	45	120	410

manufacture of some of the basic materials used in the fabrication of subsystems (steel, copper, etc.).

The annual O&M are also indicated in Table 1.3. During the earlier years, O&M costs and manpower requirements are relatively modest compared to the costs associated with manufacturing and installing the equipment. However, O&M resource requirements become significant after 1990 since the inventory of equipment already in the field (and requiring the attention of O&M personnel) starts to predominate over that installed on an annual basis.

However, the costs associated with the O&M functions are predominantly those required for semi-skilled labor which reduces the foreign exchange component of this cost factor.

The breakdown of Table 1.3 requires making assumptions relative to which components are purchased abroad and which are manufactured in Peru. Specific assumptions are outlined in the technology descriptions of Sections 3.0-6.0. In general it was assumed that components which do not require specialized technology and/or manufacturing capabilities are made in Peru. This would include such components as the towers of wind turbine units, collector array support structures, and flat plate thermal collectors. More sophisticated subsystems, such as the blades of large wind turbines and photovoltaic solar cells were assumed to be purchased abroad. These judgements are somewhat arbitrary and would require careful scrutiny in the future as a solar program develops. Also, decisions as to purchase or in-country manufacture will change in time as Peru's industrial capability improves.

The labor requirements of Table 1.3 indicates that about 250 people would be working in the solar energy sector (manufacturing plus installation) of the economy by 1985 and 550 people in 2000. The employment opportunities arising from a solar utilization are quite modest due to the relatively limited penetration of solar/wind systems in Peru during the time period of interest.

It should be emphasized that the level of specialized training required for the fabrication, installation, and operation of solar related systems is far less than that required for most advanced energy conversion facilities such as nuclear power plants or large oil refineries. For example, the manufacture of solar water heaters is primarily a simple sheet metal farming process and most of the installation effort for a solar power plant is associated with pouring concrete foundations for mounting the collector support structure. As such, it should not be difficult to train people to take advantage of the employment opportunities resulting from the solar implementation scenarios.

2.0 AVAILABILITY OF RENEWABLE ENERGY RESOURCES*

2.1 Solar Energy

There are sixteen (16) Peruvian stations taking solar radiation data, and seventy-eight (78) recording bright sunshine duration. The solar radiation stations, however, are not well-distributed and their actinographs were calibrated too infrequently so that the data recorded is of little value. The bright sunshine measurements, on the other hand, are made with less sensitive apparatus and are more reliable. In order to convert these to solar insolation, Eldon Boes estimated the radiant energy intensity of Peru's "bright sunshine" to be about 900 w/m^2; i.e., one hour of bright sunshine has a solar insolation of 0.9 kWh/m^2 (285 Btu/ft^2). Although this data only approximately accounts for the day-to-day and year-to-year variations in solar radiation, it can serve to indicate the amount of time a collector can operate and therefore, Peru's potential for tapping solar energy.

Table 2.1 shows the average daily number of hours of "bright" sunshine by season for Peru. From this data, it can be calculated that there are areas in Piura and Arequipa receiving about 2500 kWh/m^2-yr (800,000 Btu/ft^2-yr), but because of about five months a year of cloud cover, the Lima area has a yearly solar radiation of only about 1600 kWh/m^2-yr (500,000 Btu/ft^2-yr) which is comparable to that of the northeastern United States. The average insolation for the seventy-eight (78) Peruvian stations is about 1900 kWh/m^2-yr (600,000 Btu/ft^2-yr). This insolation level is also typical of the Sierra region.

2.2 Wind Energy

The available data for analyzing the wind energy resources of Peru come from several hundred sites but are limited to magnitude and direction measurements just three times a day at unknown heights, and therefore offer only a suggestion as to the capabilities of Peru's wind energy.

* Per data contained in report by Eldon Boes of Sandia Laboratories.

Station	Fall	Winter	Spring	Summer	Station	Fall	Winter	Spring	Summer
Abancay	5.5	6.9	6.3	4.4	La Molina	6.4	2.2	4.0	6.1
Accnococha	5.7	7.6	6.1	4.3	Lampas Alto No. 2	5.1	8.1	5.4	4.1
Andahusasi	7.7	7.7	8.2	6.5	Lampas Alto No. 3	5.5	8.4	6.5	5.0
Assoc. Agri. Ica	7.4	6.2	7.8	7.1	La Puntilla	7.3	4.5	6.7	7.5
Bernales	6.5	4.4	6.3	6.7	La Salle	8.5	9.7	9.8	7.5
Cajamarca	4.6	6.0	5.2	4.7	Lomas de Lachay	6.9	1.5	3.0	6.7
Calana	7.9	7.5	8.3	7.7	Los Cedros	6.6	4.9	4.8	6.1
Campo de Marte	6.0	1.1	2.8	6.3	Majoro	8.1	6.9	8.2	6.7
Canyar	6.4	2.8	4.4	6.1	Manchay Bajo	5.8	2.1	4.9	6.5
Canete	5.8	1.8	3.2	5.8	Manrique	6.4	4.6	6.2	6.7
Cartavio	6.2	4.3	5.5	6.5	Moquequa	8.9	9.5	10.3	7.9
Casagrande	6.5	4.4	5.9	6.6	Negritos	7.5	7.1	7.9	7.2
Caucato	7.8	4.3	5.4	7.3	Pacococha	6.7	9.6	7.6	5.5
Cayalti	7.7	6.7	8.0	8.1	Pachachaca	4.9	7.7	5.0	3.0
Conococha No. 1	5.5	8.5	5.9	4.6	Pampa de Majes	9.6	10.4	10.7	9.1
Nda. Chocaca	6.6	2.9	4.6	7.1	Parananga	5.9	2.2	4.3	7.1
Chachapoyas	7.1	7.6	7.5	6.9	Parque de la Reserva	6.1	1.1	2.8	5.9
Characato	8.6	9.9	10.2	7.4	Piura	7.5	6.8	7.8	7.1
Desaguadero	8.7	9.4	8.1	7.3	Puerto Chimbote	5.8	3.1	5.6	6.8
El Porvenir	4.2	5.4	4.7	4.7	Pultoc	6.8	8.6	7.6	5.1
El Tablazo	7.1	6.8	7.7	7.2	Puno	8.0	9.4	8.7	6.5
Granja Salcedo	7.7	8.8	8.5	6.4	Punta Atico	8.3	4.0	5.6	9.6
Guadalupe	6.6	5.0	6.3	6.1	Punta Coles	6.5	2.9	2.7	8.0
Guayabamba	3.8	5.4	5.3	4.6	Puracana	6.8	3.1	5.2	6.8
Huacatambo	7.1	4.8	6.6	7.3	Quillabamba	5.2	6.3	4.9	3.7
Huancabamba	3.9	4.6	4.5	4.0	Rinconada	7.1	5.4	6.9	8.2
Huanuco	5.6	7.2	5.8	4.6	San Ignacio	3.9	5.1	5.3	3.8
Huaraz	8.1	9.5	7.8	6.5	San Jacinto de Nepena	6.5	5.5	7.0	6.8
Huayao	6.5	8.2	6.4	5.5	San Jorge	4.5	6.3	5.3	4.4
Hunaya	6.9	5.1	6.9	6.8	San Ramon	4.9	6.3	5.2	3.9
Iberia	5.1	7.0	5.8	4.6	Santa Ana	7.3	8.8	7.7	5.7
Ica	7.6	6.6	8.0	7.1	Tejedores	6.2	7.1	7.8	5.9
Isla Don Martin	4.5	1.5	3.4	5.6	Trujillo (Univ.)	5.1	3.4	4.4	5.6
Isla Guanape Norte	6.5	4.4	5.4	5.9	Hacienda Valor	5.4	6.3	6.4	5.2
Lobos de Afuera	8.6	5.0	4.8	8.2	Vitor	10.1	10.1	9.9	9.3
Jayanca	6.4	6.3	6.8	6.1	Yanamachay	5.9	8.6	7.0	4.5
Kayra	6.5	8.1	6.4	4.8	Yapatera	5.2	5.3	6.2	5.7
La Joya	8.6	9.6	10.2	8.2	Yucay	4.4	6.2	5.0	3.1
Lambayeque	6.9	5.5	6.5	7.1	Yurac	3.0	4.8	4.1	2.7

Table 2.1 Average Daily Number of Hours of "Bright" Sunshine by Season for Peru (Fall = March, April, May; Winter = June, July, August; etc.)

Table 2.2 AVERAGE WIND SPEEDS BY MONTH

STATION	LAT.	LONG	ALT. (m)	TIME	J	F	M	A	M	J	J	A	S	O	N	D	AVERAGE WIND SPEED m/s	AVERAGE WIND SPEED mph
CURARAY	2.4	74.1	200	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
ZUNGACOCHA	3.8	73.3	122	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	3	3	3	3	3	2	3	3	3	3	2	3	1.0	2.2
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
TUMBRES	3.6	80.5	85	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	5	4	5	4	4	4	4	4	5	5	5	6	2.0	4.5
				19(pm)	2	1	1	1	1	1	1	1	2	2	2	3		
PETROPOLIS	4.2	70.0	300	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
CRUZETA	4.9	80.3	135	7(am)	1	1	1	1	1	1	1	1	1	1	1	1		
				13(pm)	2	3	2	2	2	3	3	3	3	2	3	3	3.7	8.2
				19(pm)	7	7	6	7	7	7	7	8	8	8	9	8		
BAYCBAR	5.8	81.0	8	7(am)	2	2	2	3	2	2	2	3	2	2	2	2		
				13(pm)	2	3	3	3	3	3	3	3	2	2	2	2	2.4	5.5
				19(pm)	3	4	3	3	3	3	3	3	3	2	2	2		
RIOJA	6.0	77.2	848	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	2	1	2	1	1	1	1	1	0	1	1	2	0.39	0.87
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
JUANCITA	6.0	74.9	150	7(am)	1	1	1	1	1	1	1	1	1	1	1	1		
				13(pm)	0	0	2	1	1	1	1	2	1	1	1	1	1.0	2.2
OLMOS	6.0	79.8	167	7(am)	1	0	0	1	1	1	1	1	1	2	2	0		
				13(pm)	4	3	3	3	3	3	3	4	4	4	4	4	3.2	7.2
				19(pm)	6	5	4	4	4	4	5	6	6	7	7	5		
OTUZCO	7.9	78.6	2620	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	3	2	3	3	3	4	4	4	4	4	4	3	1.5	3.3
				19(pm)	1	0	1	1	1	1	1	2	1	1	1	1		
TOURNAVISTA	8.9	74.7	350	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
TAYABAMBA	8.3	77.3	3250	7(am)	1	1	2	2	4	4	4	4	3	3	2	2		
				13(pm)	4	3	3	4	4	4	4	5	4	4	4	4	3.5	7.8
				19(pm)	4	3	3	3	5	5	5	5	4	4	4	5		
PAMPA WHALEY	10.9	75.3	960	7(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	1	1	1	1	1	0	1	1	1	3	4	1	0.44	0.99
				19(pm)	0	0	0	0	0	0	0	0	0	0	0	0		
LAMPAS ALTO	10.1	77.2	4030	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	7	6	7	7	7	8	8	8	8	8	7	7	3.4	7.7
				19(pm)	3	3	3	3	3	3	3	3	3	3	3	3		
INOPARI	11.0	69.6	365	7(am)	0	0	1	0	0	0	0	0	0	1	1	1		
				13(pm)	4	4	6	2	2	2	2	1	3	2	3	4	1.2	2.7
				19(pm)	0	0	1	0	1	0	0	0	0	0	1	1		
CUILLABAMBA	12.9	72.7	950	7(am)	1	1	0	0	1	1	0	1	1	1	1	1		
				13(pm)	5	5	5	5	4	5	5	5	4	5	5	5	3.3	7.4
				19(pm)	4	3	4	4	4	4	5	5	4	5	5	5		
NANA	12.0	76.8	566	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	5	6	6	6	6	4	5	5	5	6	6	6	2.2	4.8
				19(pm)	3	2	1	1	1	2	3	1	0	1	1	2		
ACCNOCOCHA	13.2	75.1	4520	7(am)	0	0	0	0	1	0	2	0	1	0	0	1		
				13(pm)	4	5	4	5	5	5	5	6	5	7	5	5	2.8	6.3
				19(pm)	3	4	3	3	3	2	2	3	3	4	4	4		
SICUANI	14.3	71.2	3550	7(am)	2	2	2	2	2	2	2	1	2	1	1	1		
				13(pm)	4	4	3	4	4	4	4	4	5	4	4	4	3.1	7.0
				19(pm)	3	4	4	4	3	2	3	4	4	5	5	4		
CHALHUANCA	14.3	73.3	2902	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	1	1	2	2	2	1	2	2	3	2	2	3	0.67	1.5
				19(pm)	0	0	0	0	0	0	0	0	1	0	1	0		
PUNO	15.9	70.0	3875	7(am)	2	2	2	2	1	2	1	1	1	2	1	2		
				13(pm)	4	4	4	4	4	5	5	6	5	6	6	5	2.8	6.3
				19(pm)	3	4	4	3	2	3	2	3	4	3	4	5		
ACARI	15.4	74.6	200	7(am)	0	0	0	0	0	0	0	0	0	0	0	0		
				13(pm)	6	6	6	5	5	4	5	5	6	6	6	6	2.7	6.0
				19(pm)	3	3	3	2	2	2	2	2	3	3	3	3		
OCONA	16.4	73.1	58	7(am)	2	2	1	3	3	2	2	2	4	3	2	2		
				13(pm)	7	8	8	8	8	8	8	8	8	8	7	8	5.2	11.6
				19(pm)	5	5	6	6	5	6	5	6	5	6	6	5		
PUNTA DE COLES	17.7	71.4	50	7(am)	5	6	5	5	4	5	5	5	4	4	5	5		
				13(pm)	7	7	7	6	6	6	7	7	6	6	6	7	5.6	12.4
				19(pm)	5	6	7	6	5	5	5	5	5	5	5	5		

Average Wind Speeds by Months for the Hours of 7, 13, and 19 at a Sample of Peruvian Sites (meters per second).

Table 2.2 provides average wind speeds over the last five (5) years by month for the hours 7, 13, and 19 for some Peruvian sites. The station Nana is in the Lima area and averages a 2.3 m/s (5.1 mph) wind, but more comprehensive data of this area would probably reveal specific sites of better wind energy.

Good wind is indicated along the southern coast by the stations Ocona and Punta de Coles of about 5.4 m/s (12 mph). Another source* reports both the southern coastal station, San Juan, and the northern coastal station, Chiclayo, as having average wind speeds of 5.7 m/s (13.7 mph). Data from Cruzeta, in the northern coastal region, also suggests good wind resources in that area.

Available data for the Sierra region (Lampos Alto and Tayabamba) indicate only marginal winds for these areas, but further measurements in more exposed areas, where wind stations are not usually located will probably reveal some good wind resources, typical of mountainous areas.

2.3 Conclusions

The data existing to date for both solar radiation and wind resources indicates the possibility for utilizing appropriate renewable energy technologies in Peru, as well as provide some rough figures with which to perform calculations to further investigate those possibilities. Before installing more than demonstration systems, however, more precise and geographically comprehensive measurements must be made in order to identify the best sites for the various technology systems.

* United States Geological Survey and Argonne National Laboratory; "Preliminary Report on the Energy Resources of Peru".

3.0 SOLAR WATER HEATING

3.1 Introduction

The heating of water for bathing and laundering purposes is still considered a luxury in Peru. Consequently, very few dwellings have hot water systems. In the heavily populated coastal areas, most washing is done with tap water without additional heating. In these areas the temperature of the tap water is sufficiently modified to make this practical (albeit there is a tendency to take short showers). In the mining towns and rural areas of the Sierra region however, the temperature of the water is always near the freezing point and consequently any washing which is done requires heated water.

There are several trends, however, which favor the introduction of solar water heaters in Peru. There has been an increase in the sale of water heaters so that presently about 20,000 units are sold annually. Electricity and bottled gas are the primary energy sources used for hot water heating in Peru with electricity appearing to be the largest factor at this time. This is due, in part, to the fact that most hot water heaters are sold in the Lima area where both these energy forms are available. In rural areas, however, the introduction of solar hot water heaters may have the effect of displacing kerosene often used for water heating and cooking* purposes.

Recent legislation requires that the larger mines provide their workers (about 60,000 miners) with hot water in order to improve health conditions. Partly in response to this legislation ITINTEC has initiated the testing of solar water heaters in a mining community and a mining company** in the Sierra region has already set-up several systems for its workers.

There appears to be, therefore, a real potential for solar water heating in Peru for domestic water purposes which will grow in future years as living standards increase and hot water is no longer considered a luxury.

This section deals primarily with residential water systems. There could, however, be a market for solar water heaters on institutional buildings (hospitals, schools, hotels, etc.) and for heating water in industrial processes.

* Only to the extent that cooking involves heating of water.
** Cia. de Minas Buenaventura S.A.

These applications are assumed to comprise about 20% of the market for solar collectors.

3.2 Technology Status

There is a variety of solar water heating systems designs which may be utilized in Peru to satisfy the needs of the different market sectors. The performance of solar water heating systems is well-demonstrated by years of experience in countries such as Australia, Israel, Japan and the United States. Hence, all the systems described herein could be used in Peru with a minimum of technical risk.

For larger systems such as might be used on institutional/commercial buildings in urban areas, active systems that use a pump to circulate the water from a storage tank up to and through the solar collector would probably be used. Figure 3.1 shows such a system schematic typical of designs used in the United States and Europe.

A second technology commonly used in non-freezing climates (Israel, Australia, etc.) which is expected to become the main source of hot water in urban residences is thermosyphon heating. The schematic of such a system is shown in Figure 3.2.* In this, the storage tank is positioned higher than the collector so that the heated water flows by natural convection from the collector into storage, removing the need for electricity consuming pumps and controls.

The collectors of the two systems mentioned above are usually a flat plate design (Figure 3.3) where the cover is generally made of glass, and sometimes of plexiglas or fiberglas. The absorber plate is typically of aluminum or copper. Copper is common for United States absorbers as it has excellent thermal conductivity yet resists corrosion unlike aluminum and its use will be assumed here because Peru has an abundance of this resource. The collector's frame can be fabricated of aluminum or steel.

A third and even simpler system which elimintes storage tank requirements is a refillable system where the absorber plate of the collector is

* Installed by Cia de Minas Buenaventura S.A. This is also the approach being pursued by ITINTEC in their R&D work.

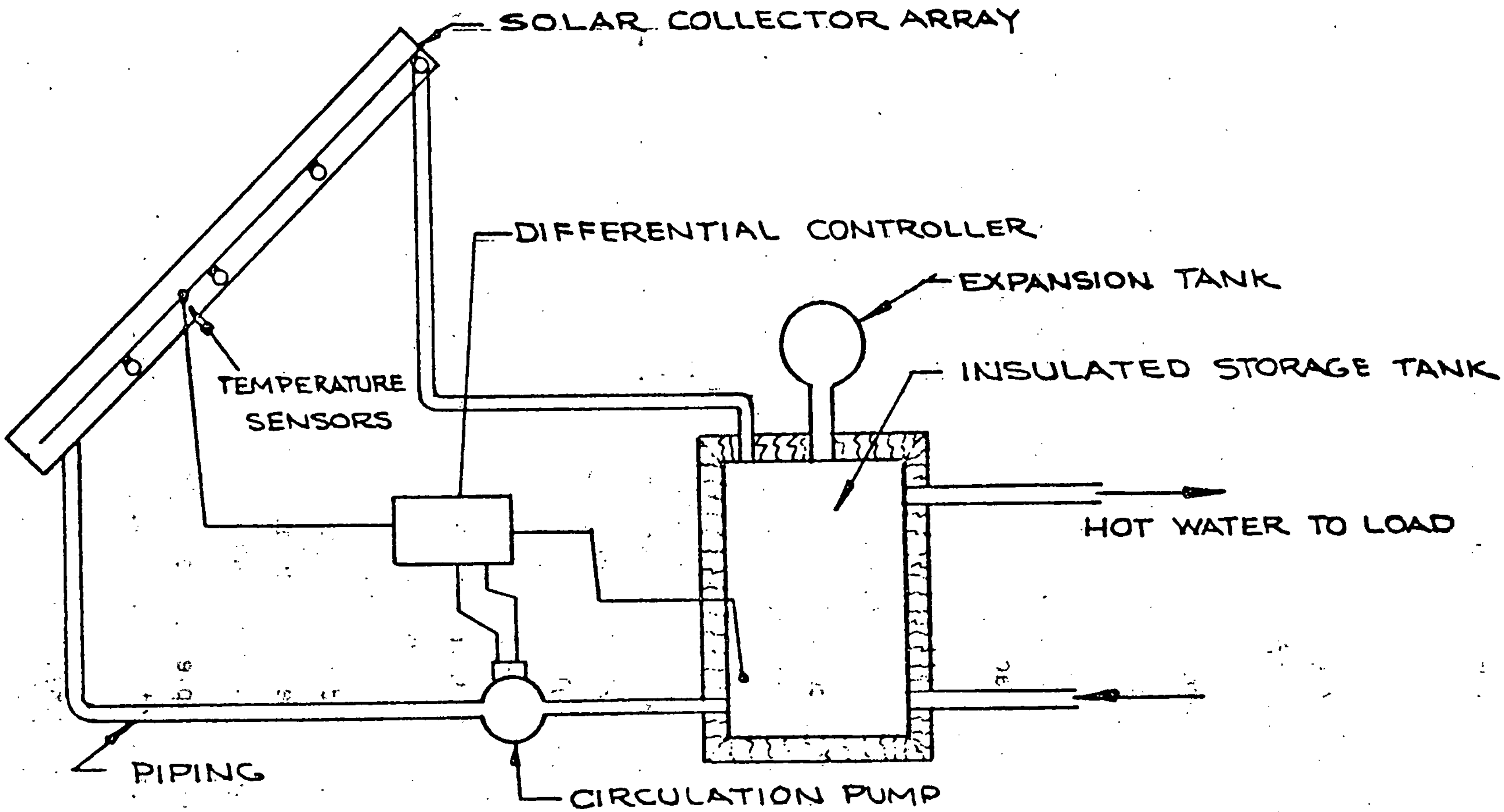
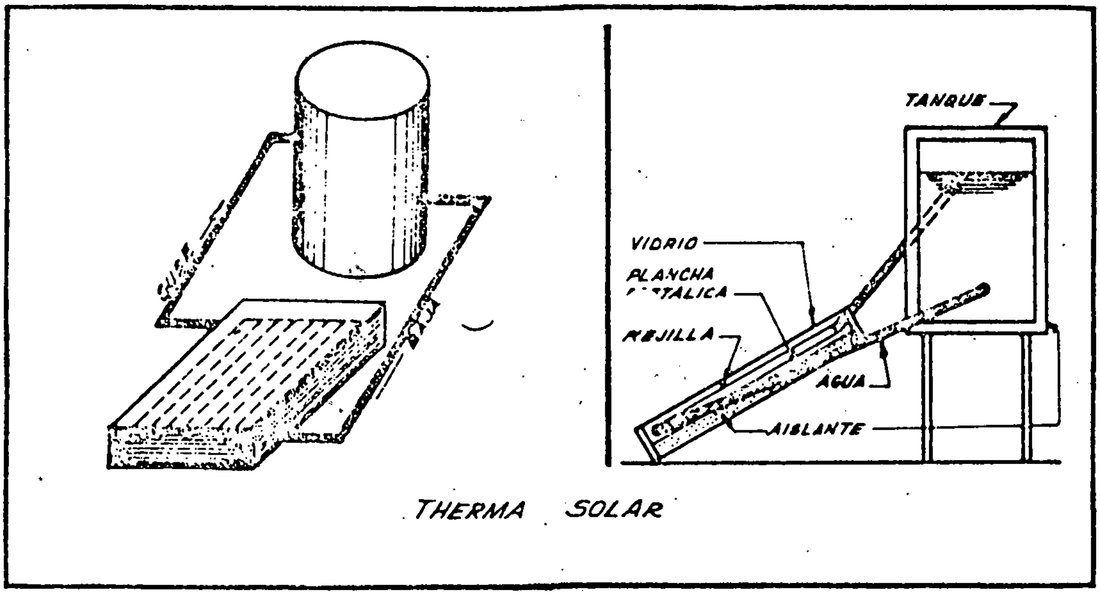


Figure 3.1 SCHEMATIC OF A PUMPED SOLAR HOT WATER SYSTEM



SOURCE: Cia de Minas Buenaventura

Figure 3.2 SCHEMATIC OF A THERMOSYPHON SOLAR WATER SYSTEM

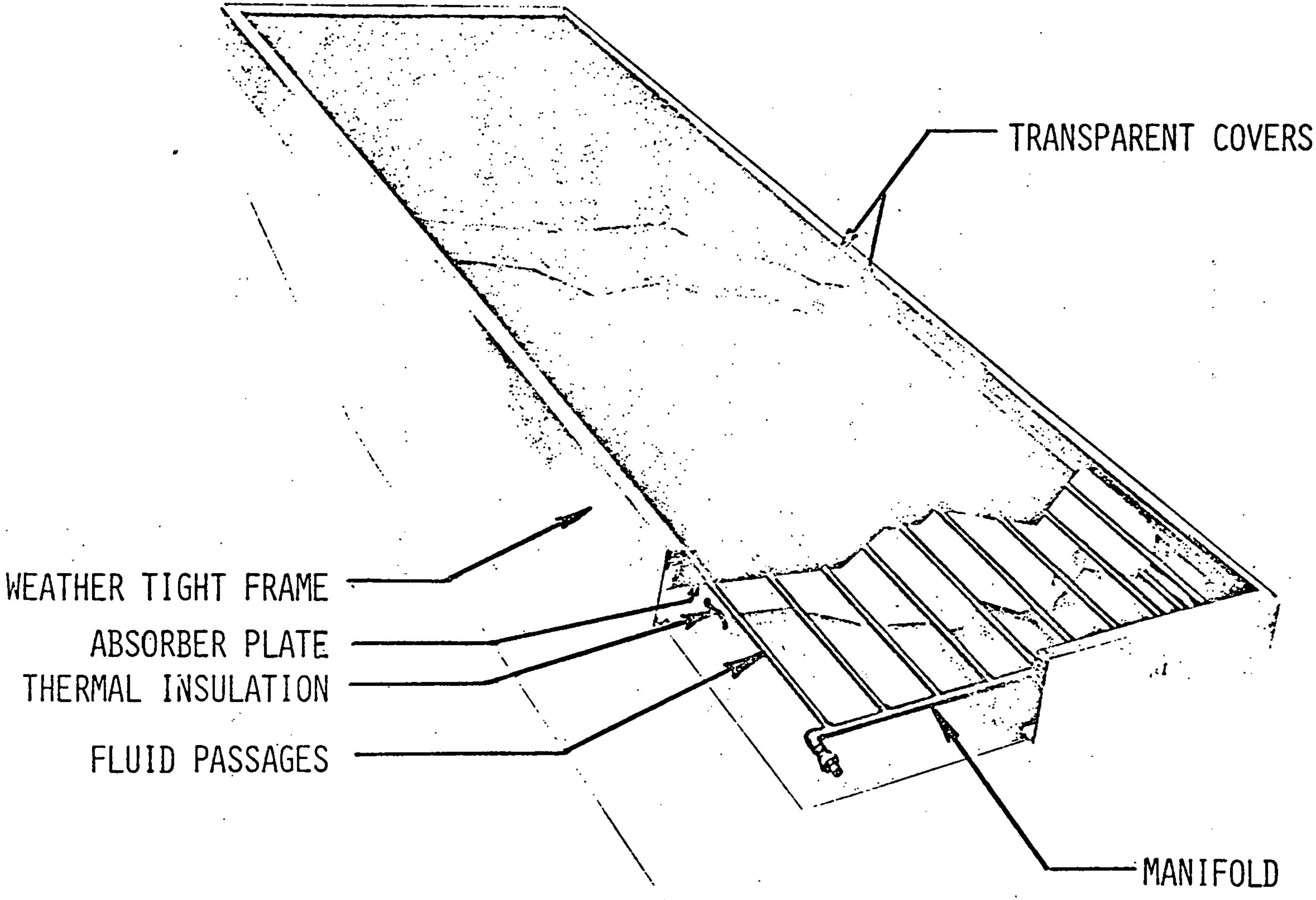


Figure 3.3 VIEW OF A TYPICAL FLAT PLATE SOLAR COLLECTOR

the storage tank (Figure 3.4). This system must be refilled after the hot water has been used and may be suitable for rural areas where this process could become just another chore, and where the more complex and expensive systems mentioned previously may not be economically feasible.

3.3 System Cost Estimates

The principal components of solar hot water systems (excluding the refillable system) include;

- Solar collector panels,
- Structure for collector mounting,
- Storage tank,
- Piping, and
- Pumps and controller (active systems only).

Estimates of the installed costs of solar hot water systems as a function of size are shown in Figure 3.5. Economics of scale are possible with active systems because of the relatively high cost of pumps and controls which are virtually the same for small and large systems. These cost estimates assume delivered collector costs of $75 per square meter and $.15 to .30 per liter (depending on size) for an insulated galvanized steel storage tank.

Installation costs are estimated to range from $30 per square meter of collector area for small systems to $20 per square meter for larger ones. However, it is likely that small prepackaged systems may be offered which could be installed by the homeowner to save on installation costs.

The economics of solar water heaters will be a primary determinant of their market acceptability. Systems economics will be influenced by;

- Initial installed costs,
- Operating and maintenance costs,
- Financing costs (interest rates),
- System life (depreciation),
- Cost of conventional energy,
- System performance (efficiency), and
- Insolation levels.

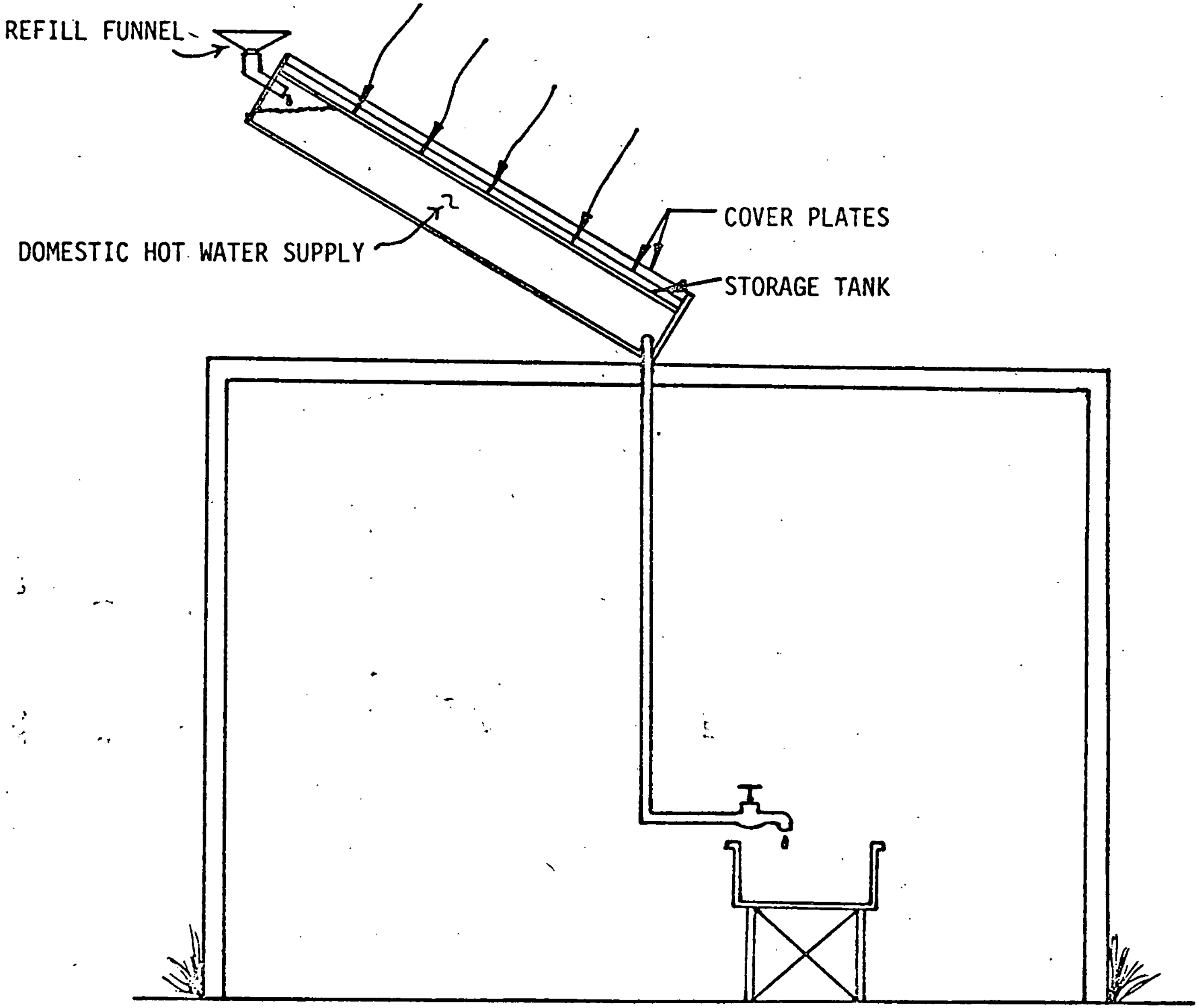


Figure 3.4 SCHEMATIC OF A "REFILL" SOLAR WATER SYSTEM

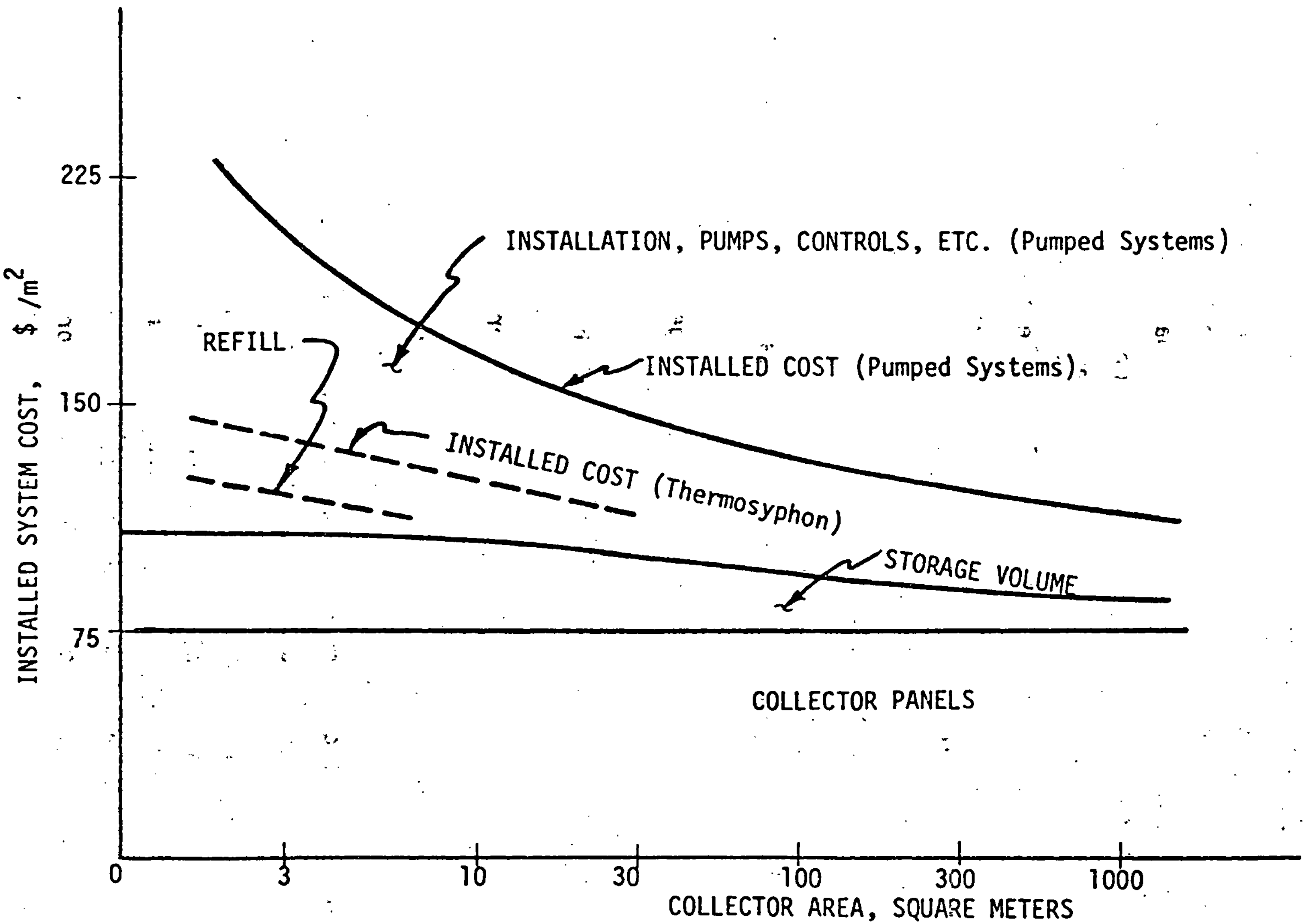


Figure 3.5 COST ESTIMATE FOR SOLAR WATER HEATERS

There are a number of different approaches for determining the economics of solar water heaters. In this preliminary analysis, the cost of delivered heat for solar water heating is calculated so as to allow comparison to the cost of kerosene, bottled gas, and electricity. The cost figures that result provide a basis for determining whether solar water heaters should be supported by government policy.

Figure 3.6 shows the cost of delivered heat for solar water heaters operating under three different solar flux regimes in Peru.

- A high insolation area (such as Arequipa),
- Average insolation conditions (the Sierra region), and
- Low flux conditions such as Lima.

The curves assume an interest rate of 8%, a 20-year life, and an operating and maintenance charge of 2% of initial costs. With fully installed systems costs of $51 per square meter, (typical of pumped systems) the cost of delivered heat would range from $2.00 per 10^9 J to $2.74 per 10^9 J depending on location.

As indicated in Figure 3.6, solar water heaters show promise of delivering heat at a lower cost than the conventional alternatives. Even in the Lima region, it appears that solar water heaters would be economically justifiable when used to supplement electric heating. This is despite the fact that for several months of the year the solar heaters would deliver a negligible amount of heat. These economic comparisons would be expected to improve in the future as the costs of conventional energy forms increase at a faster rate than the cost of solar equipment.

It should be noted that the favorable comparison between solar heaters and conventional energy sources is highly influenced by the cost of money assumed in the economic analysis. This parameter was assumed to be 8% per year in the above analysis; an assumption which may be optimistic at the present time due to Peru's present financial difficulties.

One of the compelling arguments for the widespread implementation of solar water heaters is the saving of foreign exchange. The installed

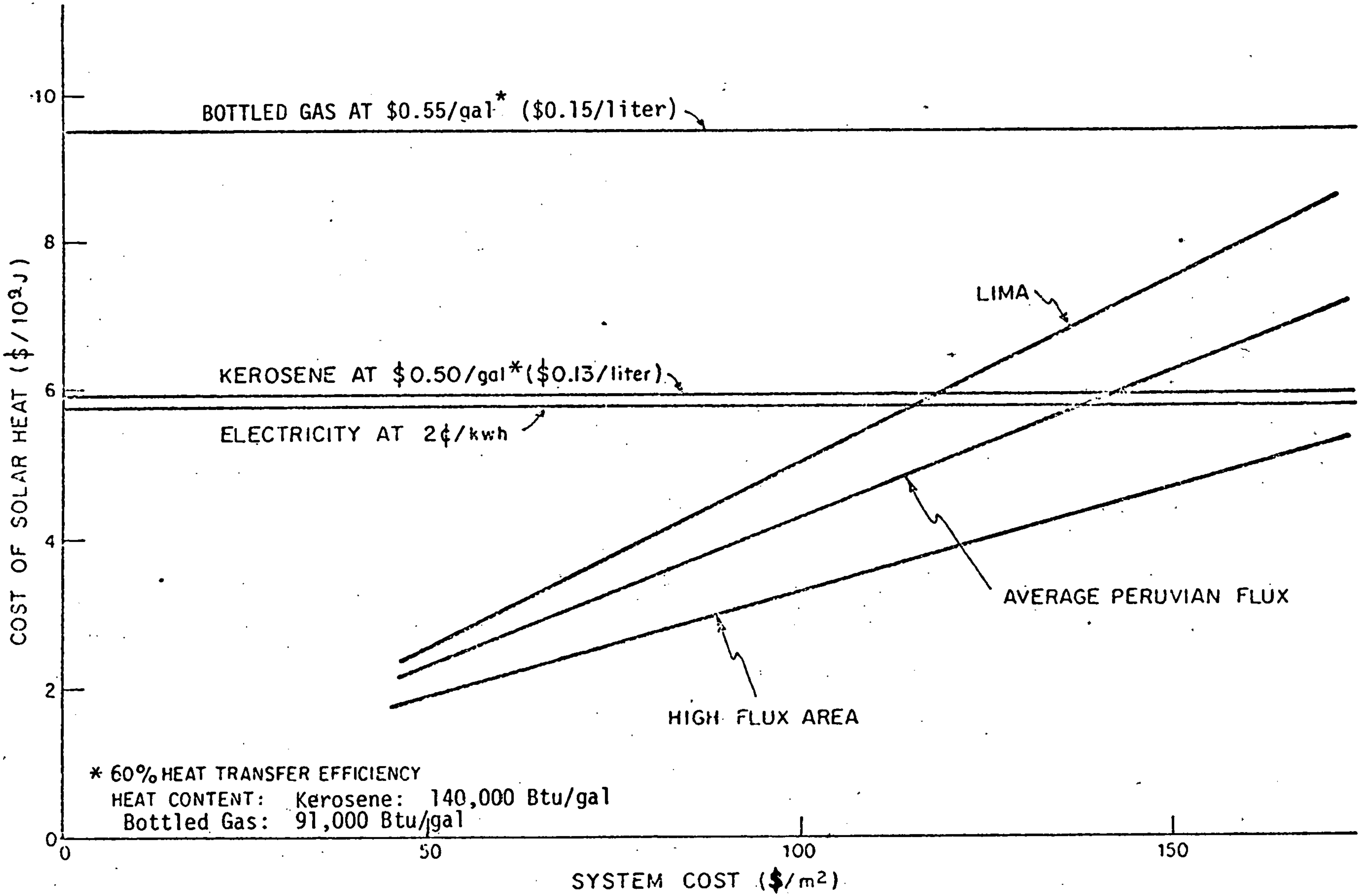


Figure 3.6 COST OF HEAT FROM SOLAR WATER HEATING SYSTEMS

systems costs have a high labor contribution, roughly 65% if all subsystems are considered. These systems could be fully manufactured in Peru using materials made by Peruvian industries. One measure of the societal cost of solar heating is that which takes into account only the foreign exchange value of materials. On this basis, solar water heaters can deliver heat at a cost of less than $\$1.78/10^9$ J which is well below the cost of kerosene.

Based on the above, it appears that solar water heating is economically justified in Peru and should see increasing acceptance in the time period of interest.

3.4 Implementation Scenario

In developing an implementation scenario, the market for solar water heaters was divided into three segments;

- Urban areas,
- Mining towns, and
- Rural areas.

Each of these market segments has special needs and characteristics which will result in a wide range of market penetrations and a variety of system configurations. The specific assumptions used in the scenario are outlined below.

(a) Urban Areas

It is estimated that about 20,000 bottled gas or electric water heaters are sold annually in Peru,* primarily in urban areas. This would imply that a significant percentage of new dwellings built under conventional financing arrangements** (about 40,000 per year) are installing water heaters. It appears, therefore, that there is an urban demand for water heating which could, in part, be satisfied with solar water heaters. One factor limiting this potential market could be the heavy concentration of the urban population which could afford water heaters being located in Lima which has a relatively poor solar flux regime (per Section 2.0).

* Per Alfredo Oliveros D.
** These would tend to be dwellings for the middle and upper classes.

Based on the above considerations, it was assumed that the potential for solar water heaters would be only a modest percentage of the conventional water heater market even in a year 2000 time frame. The number chosen was an average of about 3,000 per year during the 20-year time frame or about 60,000 units total. This represents about 10% of the total demand for hot water heaters (conventional and solar) assuming average sales of 30,000 units per year during this period.

Mining Towns:

There are presently about 60,000 miners in Peru and this number might be expected to grow to 90,000 by the year 2000 assuming growth in this industrial sector. The mining companies are now expected to provide the miners with hot water in the mining towns. Energy costs are particularly high in the remote mining areas which could provide a good opportunity for solar water heaters in a tightly controlled market environment. It was assumed that 30,000 units are installed in this market segment to the year 2000 (corresponding to their use in roughly 30% of the dwellings in mining areas).

Rural Areas:

A common comment from several individuals interviewed in Peru is that the population in rural areas of the Sierra region does not wash frequently leading to overall poor hygenic conditions and a high rate of related diseases. Several factors lead to this problem including the fact that the water in the Sierra region is always at a temperature near freezing which makes it nearly impossible to bathe in unheated water (as can be done in most coastal urban areas where the temperature of the tap water is greatly modified). In many cases, heating water for bathing (and other washing functions) is made difficult by the high expense of kerosene and/or the increasing difficulty in gathering firewood in many areas. One benefit of providing a convenient, low cost, source of hot water (simple solar water heaters) may, therefore, be improved hygiene conditions in these poor rural areas which may, in turn, have other important social/ institutional ramifications (improved productivity, reduced tendency to migrate to urban areas, etc). It should, however, be noted that the benefits resulting from use of solar water heaters in rural areas are still not well-defined and will require a carefully monitored test program to verify.

Taking into consideration the economic/social uncertainties associated with using solar water heaters in rural areas, it was assumed that their use was very limited in this market sector during the time period of interest. The resultant implementation assumption is for an average of 500 units per year for a total of 10,000 units. This very modest implementation assumption may, however, require significant modification if subsequent demonstration programs show good acceptance by rural populations for solar water heaters and their use results in quantifiable national benefits.

The resultant solar water heating scenario is summarized in Table 3.1. As indicated, by the year 2000 there would be about 100,000 residential units installed with a total collector area of over 2 million square feet.

In addition to residential systems, there is expected to be a significant market in the institutional/commercial sector on such buildings as hospitals, schools or hotels. Based on previous experience, these market sectors are assumed to add 20% in installed collector area over that indicated in Table 3.1. The total installed area for solar water heaters is therefore projected to be 2,400,000 ft^2 by the year 2000, with an annual heat delivery of 0.75 JQ (which would displace roughly 0.37 JQ of bottled gas assuming 60% heat transfer efficiency).

3.5 Resource Requirements

Table 3.2 indicates the resources necessary to implement the residential and institutional/commercial units at the rate outlined in the scenario above. Both steel and copper are produced in Peru and the range of fabricated shapes available from Peruvian industry is expected to increase in the future as these industries become more vertically integrated. As a practical matter, therefore, solar water heaters could

Table 3.1

SOLAR WATER HEATING IMPLEMENTATION SCENARIO

(Residential Only)

	Number Installed Annually (10^3 units*)		Cummulative Collector Collector Area Installed* (10^3 ft^2)	Annual Heat Delivered (10^{15} joules)
1980	Urban -	.45		
	Mining -	.22		
	Rural -	.08		
	TOTAL	0.75	15	0.00475
1985	Urban -	3.0		
	Mining -	1.5		
	Rural -	0.5		
	TOTAL	5.0	180	0.0570
1990	Urban -	3.6		
	Mining -	1.8		
	Rural -	0.6		
	TOTAL	6.0	730	0.231
2000	Urban -	4.2		
	Mining -	2.1		
	Rural -	0.7		
	TOTAL	7.0	2,030	0.643

* Assumes average collector area of 20 ft^2 per unit (1.9 m^2/unit).

Table 3.2

RESOURCE REQUIREMENTS OF SOLAR WATER HEATING IMPLEMENTATION SCENARIOS

	1985	1990	2000
	ANNUAL MATERIAL REQUIREMENTS (tons)		
Glass	140	170	200
Fiberglas	50	50	60
Steel	270	320	380
Copper	90	100	110
	ANNUAL MANPOWER REQUIREMENTS (man-years)		
Management/Technical	9	11	12
Production & Installation	90	110	130
	ANNUAL FINANCIAL REQUIREMENTS (1978 $ X 10^6)		
Materials & Components	.6	.7	1.0
Labor (Fab & Inst)	1.0	1.1	1.3
	1.6	1.8	2.3

be made using primarily indigenous labor and material resources, a factor with important foreign exchange implications. The magnitude of the requirements for materials and labor is in scale with the modest implementation rates assumed. The financial requirements imposed on the government or private resources will likewise be modest. The production of solar water heaters is labor intensive but will be welcome by Peru's fast-growing labor force.

Article 26. - Full-time workers employed by Mixed Mining Enterprises during legal working hours shall receive 10% of the company's profit in cash; this sum shall be distributed in proportion to each individual's salary as listed in the corresponding payroll.

Article 27. - Non-resident investors are hereby authorized to remit to the country of origin of the investment all the profits they are entitled to as shareholders of the Mixed National Enterprise in which they participate.

CHAPTER IV

SUPPLEMENTARY PROVISIONS

One. - The Peruvian Institute of Nuclear Energy may increase the list of radioactive ores included in the present Decree-Law on which the corresponding contracts may be entered into.

Two. - The Peruvian Institute of Nuclear Energy shall update the amounts stipulated in Articles 8 and 11 of the present Decree-Law every two years.

Three. - Mining Enterprises established in accordance with the provisions of the present Decree-Law shall be incorporated under the stipulations of Corporation Law No. 16123 but shall be exempt from the provisions of the second paragraph of Article 16 of said Law.

CHAPTER V

FINAL PROVISIONS

One. - The promotional incentives contained in Chapter II shall be in force for 30 years to run as of the date of enactment of the present Decree-Law.

Two. - All legal provisions contrary to the present Decree-Law are hereby revoked or suspended, as may be the case.

Issued by the Presidential Office, in Lima, ...

CHAPTER III

INCENTIVES

Article 21. - Mixed Mining Enterprises established in accordance with the provisions of the present Decree-Law shall pay as a sole tax the Income Tax created by Supreme Decree No. 287-68-HC. They shall apply only 50% of the rates listed in Article 119 of the General Mining Law No. 18880, and shall be exempt from the tax created by Decree-Law 21529. This benefit shall equally extend to the personnel of these enterprises exclusively for the income derived from these activities.

Article 22. - Mixed Mining Enterprises are hereby authorized to re-invest, tax-free, up to 80% of their net profits in activities inherent to their field subject to prior approval of their reinvestment programs by the Peruvian Institute of Nuclear Energy.

Article 23. - Imports for Mixed Mining Enterprises are hereby exempted from specific duties and other charges included in the Customs Tariff; from taxes on goods and services as well as from any other charges levied on imports. Such imports are limited to the equipment, new or used machinery, vehicles, inputs, and spare parts in general, which are to be employed, with exception, by said enterprise, provided they are not available in the country or do not conform with minimum stipulations as to design, quality, quantity, timing and price, subject to a favorable prior report from the Peruvian Institute of Nuclear Energy. These benefits also extend to those individuals, corporations, whether national or foreign, entering into contracts with the Peruvian Institute of Nuclear Energy to carry out prospecting and exploration activities for radioactive ores. Temporary internment of similar goods shall be taxed accordingly.

Article 24. - All those who, within the provisions of the present Decree-Law, engage in prospecting and exploration for radioactive ores, shall deduct from their gross profits the amounts spent in these activities during the corresponding fiscal year.

Article 25. - Mixed Mining Enterprises established according to the present Decree-Law are not subject to the provisions of the Part III, Section I, of the General Mining Law No. 18880.

Article 14. - The Mixed Mining Enterprise set up for the exploitation and processing of radioactive ores shall involve part or the entire area covered by exploration.

Article 15. - The enterprises participating in prospecting and exploration contracts shall submit to IPEN all the information available as regards deposits found, technical feasibility studies for their exploitation, economic profitability, operational program, evaluation on required investments, technology to be used, and all other relevant information to determine the concrete characteristics of the exploitation and processing of those deposits, without exception or limitation whatsoever.

Article 16. - The contracts entered into by the Peruvian Institute of Nuclear Energy and the establishment of Mixed Mining Enterprises in keeping with the provisions of the present Decree-Law, shall be approved by Supreme-Decree, and shall be registered in the Public Registry of Mining.

Article 17. - The Peruvian Institute of Nuclear Energy is hereby authorized to make contracts with third parties for purposes of obtaining uranium, thorium or radium, when present in the form of by-products of other ores, under the terms and conditions stipulated herein.

Article 18. - As regards mining health, disposal of radioactive waste, environmental protection and effects of radioactivity during the exploitation and processing of radioactive ores, specific international provisions as well as those stipulated by IPEN shall be complied with.

Article 19. - Enterprises entering into contracts with IPEN for the exploitation and processing of ores, shall be subject to the provisions of the International Safeguard Conventions for Nonproliferation of Nuclear Weapons signed by Peru.

Article 20. - Peruvian Law shall be the sole legislation governing the contracts executed in accordance with the present Decree-Law, whichever the nationality of the individuals or corporations involved and, in any circumstances parties shall expressly be subject to the jurisdiction and province of the judges and courts of Lima.

Article 9. - Those enterprises having completed the prospecting stage as provided for in the preceding article shall have exclusive rights to exploring the areas prospected. This right shall be exercised within a maximum period of 3 months as of the date when prospecting was concluded.

Article 10. - Exploration contracts shall cover an area not longer than 10% of the total prospecting unit and shall have a maximum duration of 2 years, at the end of which the exploration area shall be reduced by 50%. The subsequent exploration of this remaining 50% shall extend for a maximum of 3 years and the corresponding feasibility study shall be required.

Article 11. - Minimum investments in exploration contracts shall be as follows:

1st year the equivalent of S/. 80 per Hectare.

2nd year the equivalent of S/.160 per Hectare.

3rd year the equivalent of S/.280 per Hectare.

4th year the equivalent of S/.350 per Hectare.

5th year the equivalent of S/.550 per Hectare.

Article 12. - In the event that the term of the contract is not sufficient to permit coverage of the entire area, said term may be extended for an additional year provided that all conditions of the contract have been fulfilled. In such a case the minimum investment for the additional year shall not be less than that demanded for the 5th year of work.

Article 13. - The enterprise that has completed exploring activities in keeping with the provisions of the present Decree-Law, shall have the exclusive right to establish, together with the Peruvian Institute of Nuclear Energy, a Mixed Mining Enterprise to carry out the exploitation and processing of the radioactive ores deposited in the explored area. This right shall be exercised within no more than 6 months to run as of the date the exploration ended.

Article 5. - The Peruvian Institute of Nuclear Energy shall also be responsible for:

a) Exclusively carrying out all mining activities related to radioactive ores in existence in the national territory, whether directly or through third parties.

b) Controlling on behalf of the State, the mining of radioactive ores throughout the national territory.

c) Entering into agreements and maintaining links with similar foreign agencies in relation to radioactive ores.

d) Legalize contracts for performing the prospecting and exploration mining activities referred to in the present Decree-Law.

CHAPTER II

ON CONTRACTS

Article 6. - As provided for in the present Decree-Law, in setting up Mixed Mining Enterprises, it is mandatory that the participation of the Peruvian government amount to no less than 25%, both as regards the investments and the profits derived from contractual mining activities. These profits shall constitute the inherent income of the Peruvian Institute of Nuclear Energy.

Article 7. - Prospecting and exploration expenses shall be exclusively covered by the Enterprise or Enterprises engaged in those activities, but the updated total shall be computed as a contribution to the Mixed Mining Enterprise established in accordance with the present Decree-Law.

Article 8. - Prospecting contracts shall be executed for a maximum of two years, extendable for an additional year. These contracts may cover one or more prospecting units. Each prospecting unit shall cover a maximum area of 2,000,000 Hectares and shall require a minimum annual investment equivalent to S/.25 (twenty-five Soles) per Hectare.

THE PRESIDENT OF THE REPUBLIC, and THE REVOLUTIONARY GOVERNMENT Enact the following Decree-Law:

CHAPTER I

GENERAL PROVISIONS

Article 1. - Mining activities covering the prospecting, exploration, exploitation, processing, refining and marketing of the radioactive ores existing within the national territory, including those located in concessional areas and in territorial waters or in the maritime subsoil, shall be governed by the provisions of the present Decree-Law. In this context, all matters not contemplated herein shall be subject to the norms stipulated in the General Mining Law No. 18880.

Article 2. - For purpose of this Decree-Law it shall be understood that:

a) Radioactive Ores: are all minerals containing uranium, thorium or radium.

b) Radioactive Ore Deposits: the real and continuous element that contains uranium, thorium or radium in such quantities and conditions as to allow for consideration of the possibility of its economic exploitation either independently or in association with other mineral substances contained therein.

Article 3. - IPEN (the Peruvian Institute of Nuclear Energy) shall be the public agency in charge of regulating and enforcing the present Decree-Law.

Article 4. - IPEN is hereby authorized to represent the State in setting up Mixed Mining Enterprises, with natural individuals or corporations, either national or foreign, for the exploitation and processing mining activities which are the subject matter of the present Decree-Law.

DECREE-LAW

WHEREAS:

By Decree-Law 21297 the State was granted exclusive rights to the prospection, exploitation, smelting and refining of radioactive ores deposited in the national territory and, further, to the complete processing of nuclear energy, forbidding the granting of any other concessions on these substances:

The above was set forth in Article 6, clause 2 of the Constitutional Law of the Peruvian Institute of Nuclear Energy as approved by Decree-Law 21875, encompassing also the deposite of the mentioned substances located in concessional areas and territorial seas;

It is imperative to promote such mining activities in lieu of the present increasing demand for radioactive ores, given their significance in energy supplies and the part they play in national economy;

The investments demanded and the specialized technology required counsel that, without impairing direct action by the State in predetermined zones, permission be granted for contractual activities relating to the exploitation of radioactive ores in the national territory;

In order to accomplish these purposes adequate legislation is necessary for regulating State mediation and the participation of national and foreign investors in carrying out activities involved in the exploitation of radioactive ores;

In use of the powers with which they are invested, and with the approval of the Council of Ministers

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PROJECT BUDGET — UNDP CONTRIBUTION

PROGRAM V - ADVISORY SERVICES AND GENERAL COORDINATION

		TOTAL		1977		1978		1979		1980		1981	
10.	PROJECT PERSONNEL	man-months	$	man-months	$	man-months	$	man-months	$	man-months	$	man-months	$
11.	EXPERTS												
11.01	Principal Technical Advisor	60	276,000	12	55,200	12	55,200	12	55,200	12	55,200	12	55,200
11.99	Subtotal	60	276,000	12	55,200	12	55,200	12	55,200	12	55,200	12	55,200
13.	Administrative Support Personnel		30,000		6,000		6,000		6,000		6,000		6,000
15.	Official Travel		9,000		1,800		1,800		1,800		1,800		1,800
19.	Component Total		315,000		63,000		63,000		63,000		63,000		63,000
99.	TOTAL UNDP CONTRIBUTION		315,000		63,000		63,000		63,000		63,000		63,000

	Place	Date	Duration
Secretarial and auxiliary personnel	Lima	January 1977	Entire project

D. Government-Furnished Buildings, Equipment and Supplies

	Place	Delivery	Cost
Materials and Supplies			
Office materials and supplies	Lima	As needed	100,000
Buildings and Equipment			
Office facilities and equipment	Lima	January 1977	

2. Description of UNDP-Furnished Inputs

B. Assignment of International Personnel

	Place	Starting Date	Duration
Principal Advisor and Project Coordinator - Expert in nuclear planning and execution of large-scale nuclear projects, able to correctly advise the Government of Peru and IPEN in the executive preparation and implementation of the Plan and coordination of the Project	Lima	January 1977	Entire project

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS

1. Technical Report Submittal Schedule

Project progress report - every six months starting in June 1977.

Final report - at completion of execution - December 1985.

PART IV. BUDGET

APPENDIX V

PROGRAM V: GENERAL ADVISORY SERVICES TO THE GOVERNMENT AND IPEN AND COORDINATION

PART II.D. BASES OF THE PROJECT

2. PROGRAM JUSTIFICATION

The nature and complexity of the subject, in conjunction with the fact that Peru is embarking for the first time in a Nuclear Plan of this magnitude, requires outside advice in the initial stages of its execution and coordination of the assistance received.

PART II.E. OUTPUT

The activity will produce the following concrete result:

A Peruvian organization with the capability required to ensure the rational incorporation of peaceful uses of nuclear power into the national development process.

PART II.F. ACTIVITIES

	Place	Proposed Duration and Starting Date
Assistance to the Government and the Peruvian Nuclear Energy Institute for the start-up and execution of the first stage of the Nuclear Plan (1977-1981). Technical and scientific advisory services for evaluation of its progress and coordination of its activities within the technical policy and guidelines of the plan		
Coordination of the Technical Assistance furnished by UNDP and the IAEA Regular Program with the Government	Lima	January 1977 December 1981

PART II.G. INPUTS

1. Description of Government-Furnished Inputs

B. Assignment of Domestic Personnel

	Place	Date	Duration
Project Director. This position is filled by the President of the Peruvian Nuclear Energy Institute, who, acting together with the Principal Technical Advisor, will provide general orientation until the completion of the Project.	Lima	January 1977	Entire project

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PROJECT BUDGET — UNDP CONTRIBUTION

PROGRAM IV - RADIATION PROTECTION AND NUCLEAR SAFETY

		TOTAL		1977		1978		1979		1980		1981	
10.	PROJECT PERSONNEL	man-months	$	man-months	$	man-months	$	man-months	$	man-months	$	man-months	$
11.	EXPERTS												
11.2.	Radiation Protection Courses	3	12,000					3	12,000				
11.22	Installation Control and Licensing	9	36,000							6	24,000	3	12,000
11.99	Subtotal	12	48,000					3	12,000	6	24,000	3	12,000
30.	TRAINING		32,000						10,000		12,000		10,000
40.	EQUIPMENT		20,000						8,000		4,000		8,000
99.	TOTAL UNDP CONTRIBUTION		100,000						30,000		40,000		30,000

E. UNDP-Furnished Equipment and Supplies

	Place	Starting Date	Cost
Buildings and Equipment	Lima	1979/80/81	20,000

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS

1. Technical Report Submittal Schedule

Progress reports - every three months of each expert's mission, and by subject.

Final reports - upon completion of each expert's mission.

PART IV. BUDGET

2. Description of UNDP-Furnished Inputs

B. Assignment of International Personnel

	Place	Starting Date	Duration
Expert in radiation protection, capable of teaching post-graduate professional courses. Professional experience in waste and shielding control and technology	Lima	March 1979	3 months
Expert in nuclear installation licensing, protective systems and safety standards to be met by such installations	Lima	March 1980	6 months
Similarly qualified expert for control and licensing of new installations	Lima	March 1981	3 months

D. Training Provisions

Nuclear Safety and Radiation Protection Operational Control Systems	Brazil Argentina Spain France	May 1979	6 man-months
Licensing of nuclear facilities, standards and procedures	Argentina Brazil Canada Spain	March 1979	4 man-months
Licensing of nuclear facilities (particularly reactors)	Germany U.S. France Argentina	April 1980	6 man-months
Protective systems -- shielding, radioactive wastes	Canada Brazil Argentina Spain	June 1980	6 man-months
Protection technology and systems	Argentina France Spain	January 1981	4 man-months
Medicine and action in the event of nuclear accidents	Argentina Spain Brazil	March 1981	6 man-months

	Place	Proposed Duration and Starting Date
(4) Preparatory Activities To Be Undertaken By the Government		
Issuance of relevant legislation and standards	Lima	1977-1978
Execution of laboratories and facilities as provided in the 1977-1981 Nuclear Plan	Lima	1977-1978

PART II.G. INPUTS

1. Description of Government-Furnished Inputs

B. Assignment of Domestic Personnel

	Place	Date	Duration
Chief, IPEN Department of Radiation Protection and Nuclear Safety. Will coordinate activities with the experts	Lima	January 1977	Entire project
Seven professionals specializing in the science and technology of radiation protection	Lima	January 1977	Entire project
Auxiliary laboratory technicians and office personnel	Lima	January 1979	Entire project

D. Government-Furnished Buildings, Equipment and Supplies

Materials and Supplies	Place	Delivery	Cost
Office and laboratory materials and supplies	Lima	As needed	1,000,000

Buildings and Equipment	Place	Start	Cost
Laboratory under construction at IPEN	Lima	March 1977	2,500,000
Instruments and equipment	- do. -	- do. -	2,000,000

E. Miscellaneous Expenses

Operating expenses - annual budget provided in the Nuclear Plan	Lima	As needed	5,000,000

APPENDIX IV

PROGRAM IV: RADIATION PROTECTION AND NUCLEAR SAFETY

PART II.D. BASES OF THE PROJECT

2. PROGRAM JUSTIFICATION

Peaceful applications of nuclear power are not possible unless the effect of radiation is adequately controlled. In this respect, the most important provision for the use of nuclear energy is that concerning safety and protection. The Project has considered the assistance necessary to achieve this condition.

PART II.E. OUTPUT

This activity will produce the following concrete result:

A system to ensure protection of the population and the environment against the effect of the radiations.

PART II.F. ACTIVITIES

The expected UNDP assistance to this activity will start in 1979, complementing the assistance requested by the Peruvian Government from IAEA (PER/9/06) under its Regular Program. The purpose of the assistance will be to immediately overcome the country's present lack of legislation and regulatory standards in the field of radiation protection and nuclear safety and to organize the corresponding national agency in accordance with the emerging requirements of the Plan.

Such an agency will obviously require qualified personnel and appropriate equipment.

In this regard, the UNDP Project provides for the following items:

	Place	Proposed Duration and Starting Date
(1) Assistance through experts in radiation protection, licensing, radiation control, installation security, dosimetry, etc.	Lima	1979-1980-1981
(2) Teaching of radiation protection courses	Lima	1979
(3) Training of specialists abroad	Argentina Brazil Spain Mexico	1979-1980-1981

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PROJECT BUDGET -- UNDP CONTRIBUTION

PROGRAM III - NUCLEAR APPLICATIONS IN THE AGRICULTURAL SECTOR

10.	PROJECT PERSONNEL	TOTAL man-months	$	1977 man-months	$	1978 man-months	$	1979 man-months	$	1980 man-months	$	1981 man-months	$
11.00	EXPERTS												
11.13	Program III Director Course and Laboratory Organization. General Program Coordination.	30	120,000					6	24,000	12	48,000	12	48,000
11.14	Animal Husbandry and Nutrition	6	24,000							3	12,000	3	12,000
11.15	Animal Pathology	3	12,000							1	4,000	2	8,000
11.16	Plant Physiology	6	24,000							3	12,000	3	12,000
11.17	Genetic Upgrading (Inducement of Mutations)	6	24,000					2	8,000	2	8,000	2	8,000
11.18	Food and Feed Conservation	6	24,000							3	12,000	3	12,000
11.19	Forestry Research	3	12,000							1	4,000	2	8,000
11.20	Consultants	8	32,000					2	8,000	4	16,000	2	8,000
11.99	Subtotal	68	272,000					10	40,000	29	116,000	29	116,000
30.	TRAINING		44,000						19,000		16,000		9,000
40.	EQUIPMENT		153,000						30,000		100,000		23,000
99.	TOTAL UNDP CONTRIBUTION		469,000						89,000		232,000		148,000

	Place	Starting Date	Cost
Laboratory equipment and materials for animal nutrition and pathology	Lima	1980/81	11,000
Shop machinery and tools	Lima	1979/81	5,000

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS

1. Technical Report Submittal Schedule

General report of activities - quarterly, starting in July 1979 until late 1981.

Final report upon completion of each expert's mission - starting in 1979.

PART IV. BUDGET

	Place	Starting Date	Duration
Use of nuclear techniques in vegetable production	Spain Brazil Argentina	August 1980	4 man-months
Food irradiation techniques	Canada France Spain Argentina	May 1981	3 man-months
Isotopic techniques in forestry research.	Canada Spain Germany England	March 1981	3 man-months
Plant physiology	Spain Brazil Argentina Canada	April 1981	3 man-months

E. UNDP-Furnished Equipment and Supplies

	Place	Starting Date	Cost
Materials and Supplies		1979/80/81	19,000
Buildings and Equipment			
Laboratory materiel for research on plant physiology, especially photosynthesis (including instruments for field measurements of photosynthetic activity)	Lima	1979/81	8,000
2 plant cultivation chambers, germinators and accessory materiel		1981	12,000
Complementary electronic equipment counters for detection and measurement of radioactivity (including current stabilizers and other accessories)		1981	6.000
Neutron sondes and accessories		1979	12,000
Biological materials irradiation unit (Gamma cell type)		1980	30,000
2 vehicles		1979/80	12,000
Mass spectrometer and accessories		1980/81	38,000

	Place	Starting Date	Duration
Expert in the application of nuclear techniques in plant genetics (inducement of mutations). Course teaching, laboratory and field work	- do. -	1979/80/81	6 man-months
Expert in the use of intense radiation sources to preserve food and feed, course teaching, conferences, and analysis of potential in Peru	- do. -	1980/1981	6 man-months
Expert in the application of radioisotopic techniques in forestry research - course teaching - conferences and laboratory work and field experiments	- do. -	1980/1981	3 man-months
Consultants, particularly with respect to the use of analytical and experimental techniques	- do. -	1979/80/81	8 months

D. Training Provisions	Place	Starting Date	Duration
Radioisotopic techniques Analysis	Brazil Spain Argentina France	March 1979	6 man-months
Plant Physiology - Photosynthesis	Spain France Brazil	May 1979	6 man-months
Application of radioisotopes Radiochemistry	France Spain Argentina Brazil	July 1979	3 man-months
Radiation protection - Dosimetry	France Spain Argentina Brazil	July 1979	4 man-months
Animal nutrition evaluation study	Argentina U.S. Spain	May 1980	6 man-months
Process and evaluation of mineral nutrition in plants	Spain France Argentina Brazil	May 1980	6 man-months

D. Government-Furnished Buildings, Equipment and Supplies

	Place	Delivery	Cost
Materials and Supplies			
Office and laboratory materials and supplies	- do. - (UNA)	- do. -	1,290,000
Buildings and Equipment			
Radioisotope laboratory, winter pastures, experimental plots, etc.	Lima UNA	Starting in 1977	6,000,000
Complementary equipment	Lima UNA	- do. -	1,100,000

E. Miscellaneous Expenses

	Place	Delivery	Cost
Equipment maintenance, field experiment support	Lima UNA	1979	1,000,000

2. Description of UNDP-Furnished Inputs

B. Assignment of International Personnel

	Place	Starting Date	Duration
Program III Director. Expert in organization of courses and laboratories. Coordination of entire activity in use of radioisotopes in agriculture and cattle raising Specialist in soils and fertilizers.	Lima UNA	June 1979	30 man-months
Expert in the application of nuclear techniques in animal nutrition, course teaching and applied work	Lima UNA	1980/1981	6 man-months
Expert in the application of nuclear techniques in animal pathology, course teaching and guidance of applied work	- do. -	1980/1981	3 man-months
Expert in the application of nuclear techniques, plant physiology, course teaching, applied work	Lima UNA	1980/1981	6 man-months

	Place	Proposed Duration and Starting Date
Acceptance of equipment furnished by UNDP	Lima	January 1979 to late 1981
Training of professionals	Abroad	January 1979 to late 1981
Field work and research	Lima	January 1979 to late 1981

(6) Preparatory Activities To Be Undertaken By the Government

Installation of radioisotope laboratory and equipping of experimental winter pasture and plots	Lima UNA	1977-1978
Coordination of Pilot Center activities with other universities and institutions connected with agriculture	Lima and other regions	1977-1978
Formation of required Peruvian personnel staff	Lima	1977-1978

PART II.G. INPUTS

1. Description of Government-Furnished Inputs

B. Assignment of Domestic Personnel

	Place	Starting Date of Service	Duration
Program director at Agricultural University - a nuclear physics specialist who will coordinate the activity with the experts	Lima UNA	January 1979	Entire project
Two specialists in isotope applications in soils and mineral nutrition	Lima UNA	January 1977	- do. -
Two biophysics specialists	- do. -	- do. -	- do. -
Professors in physics and meteorology departments	- do. -	- do. -	- do. -
Radiology professor	- do. -	- do. -	- do. -
Administrative personnel and auxiliary laboratory personnel	- do. -	- do. -	- do. -

2. Better food conservation systems.

3. Pest eradication.

4. Introduction of more productive species.

PART II.F. ACTIVITIES

(1) Preparatory Stage

The support begun by IAEA in the form of experts, equipment and scholarships under PER/5/07 and PER/5/08 will be continued during the initial years of the Project, while the construction and equipping of the Radioisotope Laboratory, the Pilot Center and the Complementary Facilities at the National Agricultural University (UNA) are under way.

Massive UNDP-IAEA assistance will start to be provided to this activity in 1979, as follows:

(2) Activities	Place	Proposed Duration and Starting Date
Organization of courses, laboratory research and work in experimental plots and in the field on the application of nuclear techniques to plant physiology, genetic upgrading, animal husbandry, animal nutrition and metabolism, forestry research, soils, fertilizers, mineral nutrition, food and feed conservation, etc.	Lima and elsewhere in Peru	January 1979 until late 1981
(3) Furnishing of equipment, instruments and special materials for radioisotope applications in the agricultural sector	Lima	January 1979 until mid-1981
(4) Preparation of specialists from UNA and other centers and agencies to teach, apply and control nuclear techniques in the sector	Lima and elsewhere in Peru	January 1979 to late 1981
(5) Summary		
General Activities		
Services of a specialist responsible for course organization and general coordination	Lima and other project areas	January 1979 to late 1981
Services of seven or eight additional experts in animal husbandry, plant physiology, genetics, food preservation, fertilizers, soils and fertilizers, radiation protection	Lima and other project areas	January 1979 to late 1981

APPENDIX III

PROGRAM III: NUCLEAR APPLICATIONS IN THE AGRICULTURAL SECTOR

PART II.D. BASES OF THE PROJECT

2. PROGRAM JUSTIFICATION

The use of nuclear techniques offers significant, very valuable resources which can act rapidly, efficiently and economically to solve various of Peru's agricultural problems, such as soil fertility and aggregate fertility, moisture control, plant genetics and physiology, pest control and disinfestation of grain, qualitative and quantitative improvement of food protein content, and so forth.

This is why the Peruvian Nuclear Plan has given special priority to a program of nuclear applications in the agricultural and livestock sector, intended to increase food productivity; this program includes the future establishment of a Pilot Center for Applications of Nuclear Sciences in the Agricultural Sector.

The means to permit developing this activity immediately and effectively is already in existence; it specializes in teaching leading to the use of isotopes and radiation and to the organization of post-graduate courses on the use of isotopes and radiation in agricultural research.

In fact, the initial nucleus of the projected Pilot Center will be the present Radioisotope Laboratory and teaching program in technical nuclear applications of the National Agricultural University (UNA), created by virtue of the Agreement between UNA and JCEA (now IPEN) and implemented with assistance from the International Atomic Energy Agency (PER/5/07).

The primary purpose of the Pilot Center will be the practical dissemination of agricultural applications of nuclear sciences in the rural areas, with the objective of increasing the output of the farm sector and improving the techniques employed in it.

To carry out its mission and attain the proposed objective, the Pilot Center will coordinate its activities by means of bilateral contracts and/or agreements with other universities and institutions acting in the field. The Pilot Center will provide to these organizations the teaching, research and facility utilization services they may require, provided such services lie within its available capacity and are intended for the proposed end.

In principle, the selected areas for priority concern include soils and fertilizers, plant physiology, animal husbandry and genetic improvement. Research activities have already begun in the first of these areas.

PART II.E. OUTPUT

This activity will produce the following concrete results:

1. Greater and better production of foodstuffs,

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PROJECT BUDGET -- UNDP CONTRIBUTION

PROGRAM II - EVALUATION OF URANIUM RESOURCES

		TOTAL man-months	TOTAL $	1977 man-months	1977 $	1978 man-months	1978 $	1979 man-months	1979 $	1980 man-months	1980 $
10.	PROGRAM PERSONNEL										
11.	EXPERTS										
11.07	Program II Director	36	144,000	6	24,000	12	48,000	12	48,000	6	24,000
11.08	Sedimentary and Stratigraphical Geologist	27	108,000	3	12,000	12	48,000	12	48,000	6	24,000
11.09	Aerial Prospecting Expert	6	24,000	3	12,000	3	12,000				
11.10	Geochemist	24	96,000			12	48,000	12	48,000		
11.11	Economic Geologist	14	56,000					12	48,000	2	8,000
11.12	Uranium Sedimentation Geologist	30	120,000			12	48,000	12	48,000	6	24,000
11.99	Subtotal	137	548,000	12	48,000	51	204,000	60	240,000	14	56,000
16.	Other Costs		12,000				6,000				6,000
19.	Total		560,000		48,000		210,000		240,000		62,000
29.	Subcontracts		11,000				6,000		5,000		
30.	TRAINING		132,000		54,000		40,000		30,000		8,000
40.	EQUIPMENT		184,000		65,000		76,000		40,000		3,000
50.	MISCELLANEOUS EXPENSES		16,000		1,000		5,000		5,000		5,000
99.	TOTAL UNDP CONTRIBUTION		903,000		168,000		337,000		320,000		78,000

- Reports on test drillings in the areas
- Reports on 1979 field operations
- Reports on economic evaluations pertaining to the areas
- Review of Program II.

These reports will be prepared and submitted to the Government immediately upon completion of each stage of the work. In addition, reports discussing the progress of the Project will be prepared every six months, in accordance with a schedule to be jointly established by the Government, UNDP and IAEA.

PART III.C. SPECIAL CONSIDERATIONS

1. Provisions on Complementary Government Activities

The Peruvian Government recognizes that, given the country's geological and morphological reality, the planned uranium resources evaluation and development activity will have a scale of operations that may well go beyond any more detailed execution program. Consequently, the Government will strive to apply the most modern prospecting methods and techniques in the selected and evaluated areas, so as to achieve the goals of the Project to the greatest extent possible. While uranium reserves may indeed be discovered in these areas, one of the principal objectives of the Project is to train Peruvian personnel so that, once the Project has been completed, they will be able to extend their activities to other parts of the country under Peru's long-term uranium exploration program.

If any of the areas included in the activity should be found to contain a significant, economically workable deposit of uranium, the Peruvian Government intends to then prepare a Detailed Working Plan to extract the ore as soon as it has available the appropriate technical conditions.

The Peruvian Government recognizes that the areas chosen in the preliminary selection cover a considerable extent and that each of them possesses its own characteristic geomorphology. As a result, it will be necessary to redefine the covered areas and conditions in order to limit their extent to a value that can be adequately investigated.

PART IV. BUDGET

- The Peruvian Nuclear Energy Institute will coordinate the active participation of the following national organizations in the execution of the project:

    - Institute of Geology and Mining
    - Petróleos del Perú
    - National Aerophotographic Service
    - Empresa Minero-Perú
    - Empresa Centromina
    - National Office of Natural Resource Evaluation
    - Transportation Service of the Peruvian Air Force
    - Directorate of Highways, of the Ministry of Transportation
    - Military Geographic Institute
    - Mining Science and Technology Institute.

  All stages of Program II will be implemented after study in coordination with the responsible technical personnel of the above-mentioned geological and mining organizations, as called for by the nature of the matter, with the participation of the UNDP and IAEA director representatives accredited to the Project.

  The progress of the program will be reviewed annually in coordination with the planning sector of the Ministry of Energy and Mines and the IPEN-UNDP technical office.

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS

1. Technical Report Submittal Schedule

The Implementing Agency will draft technical reports on the following subjects for submission to the Government:

SUBJECT

- Preliminary reports on the geological suitability of the areas
- Preliminary reports on the aerial prospecting of the areas
- Reports on 1978 field operations
- Reports on radiometric prospecting of the areas, including both self-carried and terrestrial prospecting in general
- Reports on geochemical exploration

	Place	Delivery Date	Cost (Dollars)
4 binocular microscopes for mineralogy	Lima and field	July 1978	2,000
Sample preparation (grinders, mixers, splitters, etc.)	Lima	July 1978	8,000
Analytical Laboratory Equipment			
1 fluorimeter (w/ 40 platinum discs)	Lima	July 1977	7,500
1 atomic absorption spectrophotometer	Lima	January 1978	24,000
Miscellaneous Field and Office Equipment			
Field geological equipment	Project areas	July 1977	3,000
Field geochemical equipment	Lima and project areas	July 1977	1,000
Office drafting equipment	Lima	July 1977	3,000
Radio communication equipment	Lima and project areas	January 1978	6,000
Miscellaneous Expenses			
Equipment use and maintenance			3,000
Report preparation			8,000
Miscellaneous			5,000

PART II.K. INSTITUTIONAL STRUCTURE

- Program II will be managed by the Office of the Uranium Exploration Plan of the Peruvian Nuclear Energy Institute's Division of Raw Materials.

  Acting within the scope stipulated by the General Law on Peruvian Mining (Decree-Law 18880), the Peruvian Nuclear Energy Institute (IPEN) will inform the Government of the need to reserve for the use of the State the areas included in the Peruvian Uranium Prospecting Project, as well as any changes that may be made to them, for as much time as may be necessary.

	Place	Delivery Date	Cost (Dollars)
Buildings and Equipment			
Vehicles			
1 van or light truck	Lima and project areas	June 1977	6,000
4 jeep-type vehicles	Lima and project areas	June 1977	24,000
Drilling Equipment			
1 percussion hammer, cobra type, or light prospecting drill	Lima and project areas	July 1979	11,000
Field Radiometry Equipment			
9 scintillation counters	Lima and project areas	June 1977	16,500
1 radon monitor or emission meter	Lima and project areas	January 1978	4,500
1 test-pit radiometric sounding system, with scintillation sound	Lima and project areas	January 1978	18,000
1 field gamma spectrometer	Lima and project areas	January 1978	9,000
Field Geophysics Equipment			
1 complete resistivity-type exploration set	Lima and project areas	June 1978	2,900
1 proton magnetometer	Lima and project areas	June 1978	3,100
Laboratory Equipment (Mineralogy and Photointerpretation)			
Photointerpretation equipment (to be specified)	Lima and field	July 1978	5,000

	Place	Starting Date	Duration
- Working of uranium deposits	France U.S. Canada	July 1978	6 months (2)*
- Training of prospectors	France Spain Argentina (Brazil)	September 1977	6 months (2)*
- Economic evaluation of deposits	France	April 1979	6 months (2)*
- Planning and execution of test borings	Argentina Spain	October 1978	3 months (2)*
- Calculation of reserves in sedimentary rocks	Argentina U.S.	March 1978	6 months (1)*
- Maintenance and nuclear instrumentation for prospecting	France Canada U.S.	January 1978	3 months (2)*
- Scientific tour for the Assistant Project Director	Argentina U.S. Canada Australia	1978-1979	6 months (1)*

D. UNDP-Furnished Equipment and Supplies

	Place	Delivery Date	Cost (Dollars)
Materials and Supplies			
Supplies			
Chemical supplies, laboratory replacements and materials	Lima	From July 1977	8,000
Materials, spares and accessories for geological, radiometric, geochemical and geophysical prospecting and sounding equipment	Lima and field	From July 1977, as needed	11,500
Materials and spares for vehicles	Lima and project areas	From July 1977, as needed	10,000

		Place	Starting Date	Duration
	Project Supervision Duties	Lima and project areas	1978-1980	

C.	Subcontracts	Place	Starting Date	Cost (Dollars)
	Computer processing of sampling data	Canada	1978-1980	8,000
	Verification of chemical and mineralogical analysis	Austria and other countries	1978-1980	3,000

D.	Training Provisions	Place	Starting Date	Duration
	- Methodology of uranium exploration in sedimentary rocks	UNDP Project Argentina U.S.	September 1977	3 months (4)*
	- Aerial radiometric prospecting	UNDP Project Canada Argentina	September 1977	3 months (2)*
	- Geochemical prospecting techniques	UNDP Project Canada Spain France	September 1977	6 months (2)*
	- Geological photointerpretation	Colombia Netherlands Spain	February 1977	6 months (2)*
	- Mineralogy and petrography of radioactive minerals	France U.S. Spain	February 1978	6 months (2)*
	- Geophysics/Radiometric profiling of test pits	U.S. Canada Argentina	February 1978	3 months (2)*
	- Treatment and concentration of radioactive minerals	Argentina Spain U.S.	February 1978	6 months (2)*

* ( ) = Number of scholarships.

	Place	Starting Date	Duration
<u>Uranium geologist specializing in sedimentary areas</u>			
Geologist specializing in uranium prospecting in sedimentary formations. Should also have experience in radiometric prospecting (both self-carried and terrestrial in general), photointerpretation, radiometric sounding of test pits and evaluation of sounding data	Lima	October 1977	30 man-months
<u>Expert in aerial radiometric prospecting</u>			
Geologist or geophysicist specializing in management of aerial radiometric prospecting by total counting or gamma spectrometry and using fixed-wing aircraft or helicopters, and in the recording and interpretation of the obtained data	Lima and field	October 1977	6 man-months
<u>Stratigraphic expert</u>			
Geologist with experience in sedimentary environments, stratigraphic and paleographic correlations, and uranium deposition environments similar to the cordilleran deposits. Useful knowledge of geology and evolution of the Andean Cordillera	Lima and field	January 1978	27 man-months
<u>Geochemist</u>			
Geologist or geochemist with experience in the planning and management of modern chemical methods of prospecting for uranium and other methods, as well as in data interpretation using computer programs. Will also manage the radon method prospecting.	Lima and field	January 1978	24 man-months
<u>Economic geologist</u>			
Economic geologist or economic mining engineer with experience in the evaluation of sedimentary and veined uranium deposits. A knowledge of production of uranium as a byproduct is desirable.	Lima and field	October 1978	14 man-months

Buildings and Equipment	Place	Starting Date	Cost (Soles)
Buildings and facilities for laboratories, offices, equipment, etc.	Lima	As needed	24,800,000
Vehicles			
- 4 jeeps	Field	July 77	4,240,000
- 4 station wagons	Field	January 78	
- 4 jeep vans	Field	January 78	
Prospecting Equipment			
- Aerial prospecting	Field	July 77	1,650,000
- Geochemical prospecting	Field	July 77	2,070,000
- Terrestrial prospecting	Field	July 77	1,650,000
- Test boring equipment	Field	As needed	4,950,000
Laboratory Equipment			
- Chemical analysis	Field	As needed	1,250,000
- Photointerpretation	Lima	July 77	850,000
Miscellaneous Expenses			
Aerial services	Field	As needed	32,000,000
Operational expenses	Field	As needed	15,000,000
Equipment use and maintenance	Field	As needed	3,000,000
Miscellaneous	Lima and field	As needed	1,825,000

2. Description of UNDP-Furnished Inputs

B. Assignment of International Personnel

	Place	Starting Date	Duration
Program II Director			
Geologist with extensive experience in the planning and execution of uranium prospecting projects using modern techniques. Will coordinate the work of the experts and supervise and expedite the advisory services in accordance with the dates and details specified under ACTIVITIES in this document.	Lima and field	July 1977	36 man-months

	Place	Starting Date of Service	Duration
Three terrestrial prospectors (engineers)	- do. -	January 1977	126 months
One geologist for laboratory work	- do. -	January 1977	42 months
Non-Professional Personnel			
One secretary	Lima	January 1976	54 months
One secretary	Lima	January 1977	36 months
Four office clerks	Lima and field	January 1977	156 months
Three drivers	- do. -	July 1977	117 months
Three drivers	Lima and field	1978	81 months
Three semi-skilled technicians	- do. -	January 1976	162 months
Five semi-skilled technicians	- do. -	April 1978	195 months
Five semi-skilled technicians	- do. -	January 1978	150 months
Ten semi-skilled technicians	- do. -	January 1978	180 months

C. Subcontracts

Aerial prospecting subcontract with a Peruvian firm	Field	April 1978	14-16 months

D. Government-Furnished Buildings, Equipment and Supplies

Materials and Supplies	Place	Starting Date	Cost (Soles)
Fuel for aerial and terrestrial vehicles and equipment	Lima and field	As needed	2,526,000
Office and other supplies	Lima and field	As needed	820,000

PART II.C. INPUTS

1. Description of Government-Furnished Inputs

B. Assignment of Domestic Personnel

	Place	Starting Date of Service	Duration
One Chief Engineer from the Uranium Exploration Division, to furnish information and assistance to the UNDP experts	Lima and field	January 1977	42 months
One aerial prospector (geologist)	Lima and field	January 1977	42 months
Two terrestrial prospectors (geological engineers)	Lima and field	January 1976	108 months
One terrestrial prospector (geologist)	Lima and field	June 1976	49 months
One electronic engineer	- do. -	July 1977	36 months
One geophysical engineer	- do. -	July 1977	36 months
Three terrestrial prospecting engineers	- do. -	January 1976	162 months
One chemical engineer for laboratory work	Lima	January 1976	54 months
Two geochemists (geologists)	Lima and field	January 1977	84 months
One technical draftsman	- do. -	January 1977	42 months
One mining engineer	- do. -	July 1978	30 months
One laboratory chemist	Lima	July 1978	30 months
One photointerpreter (geologist)	Lima and field	January 1977	42 months
One drilling engineer	- do. -	July 1978	24 months
One aerial prospector	- do. -	July 1978	24 months
One aerial prospecting engineer	- do. -	July 1978	12 months
Three terrestrial prospectors	- do. -	January 1977	126 months

	Place	Proposed Duration and Starting Date
Preliminary training of contracted Peruvian personnel in aerial and terrestrial methods of radiometric surveying and in geochemical techniques, followed by on-the-job training in the field	Lima and Program Areas	January 1977 to May 1977
Contacts with suppliers of aerial radiometry equipment and helicopters for aerial prospecting operations	Program Areas	October 1977
Field Operations		
Planning of field operations by the Program II Director and Assistant Director	Lima and Program Areas	July 1977 to November 1977
Aerial and geochemical reconnaissance surveys of selected project areas	Program Areas	April 1978 to November 1979
Terrestrial [radiometric] and geological reconnaissance surveys	Program Areas	April 1978 to November 1978
Aerial and terrestrial radiometric prospecting, geophysical and geochemical studies, with the participation of laboratories	Program Areas and Lima	November 1978 to end of program
Exploratory borings (geological data), radiometric soundings of test pits	Program Areas	April 1979 to end of program
Economic evaluation of uranium occurrences	Program Areas and other areas of interest to IPEN	April 1979 to end of program

(7) Training

a) Peruvian counterpart personnel will be granted 25 scholarships, for a total of 132 man-months, to study abroad various topics pertaining to the execution of the program.

b) In addition, IPEN's Center for Advanced Nuclear Studies (CSEN) has scheduled training courses for personnel to be contracted for the project, to be taught with the assistance of Peruvian or foreign experts. These courses will cover technical aspects related to terrestrial, aerial, geochemical and other prospecting of radioactive materials.

Whenever a discovery is made which clearly indicates the finding of a uranium deposit of considerable potential value, the Government, UNDP and IAEA will be immediately notified by means of a Special Report of Discovery, so that they may consult with each other with respect to any changes to the prospecting program that may be advisable as a result of the discovery.

(6) Program II General Activities

	Place	Proposed Duration and Starting Date
Services of Program II Director, responsible for the preparation and execution of the plan of work	Lima and Program Areas	3 years, from 1 July 1977 to 30 June 1980
Services of another seven short-term experts and consultants in prospecting, evaluation and analysis of uranium	Lima and Program Areas	Up to 3 years, between 1 July 1977 and 30 June 1980
Delivery of equipment furnished by UNDP	Lima and Program Areas	1977-1980
Training of approximately 25 geologists, mining engineers and chemists abroad	Spain, France, U.S., Brazil, Canada, etc.	Total of 132 man-months between 1977 and 1980
Field work -- geological, radiometric and geophysical reconnaissance surveys, borings	Program Areas	3 years, from 1 July 1977 to 30 June 1980
Preparatory Activities To Be Undertaken By the Government to Ensure Completion Of the Project Within the Scheduled Term		
Compilation of background data; preparation and furnishing of all reports and maps pertaining to all work previously accomplished in the project areas and required for execution of the program	Lima	October 1976 to March 1977
Procurement of such sets of topographic maps and aerial photographs as may be required for Program II	Lima	January 1977 to March 1977
Appointment and marshalling of all Peruvian personnel needed for the initial stages of the program	Lima	January 1977 to March 1977
Selection and contribution of equipment from available Peruvian organizations and laboratories	Lima	January 1977 to March 1977

- Use of terrestrial radiometric and geochemical methods, aerial prospecting, etc., until the selected areas mentioned in the preceding item are completely surveyed.

(4) Regional Prospecting

On the basis of the results of the initial reconnaissance survey activities, the most promising areas will be studied in more detail, as follows:

- Geologic maps based on the aerial photography products and the overland reconnaissance activities will be prepared, to the extent necessary for the prospecting task.

- High resolution aerial radiometric survey.

- More detailed geochemical analyses of water and alluvial deposits, radiohydrological studies, and more detailed surface radiometric surveys.

- Preparation of maps and reports showing anomalous areas and geological, mining, radiometric and geochemical data.

(5) Systematic Prospecting

The information obtained in the first two stages will make it possible to determine the most promising areas, which will then be covered by a systematic prospecting effort including the following methods:

- Terrestrial radiometric survey and detailed geologic survey (1:5,000 - 1:10,000 scale) of the selected areas.

- Systematic geochemical analyses in areas suitable for the use of this technique.

- Systematic reconnaissance using soil and water radon content techniques.

- Surface geophysical studies, whenever indicated by the geological characteristics.

- Whenever appropriate, opening of trenches in outcroppings and systematic sampling of uranium indications.

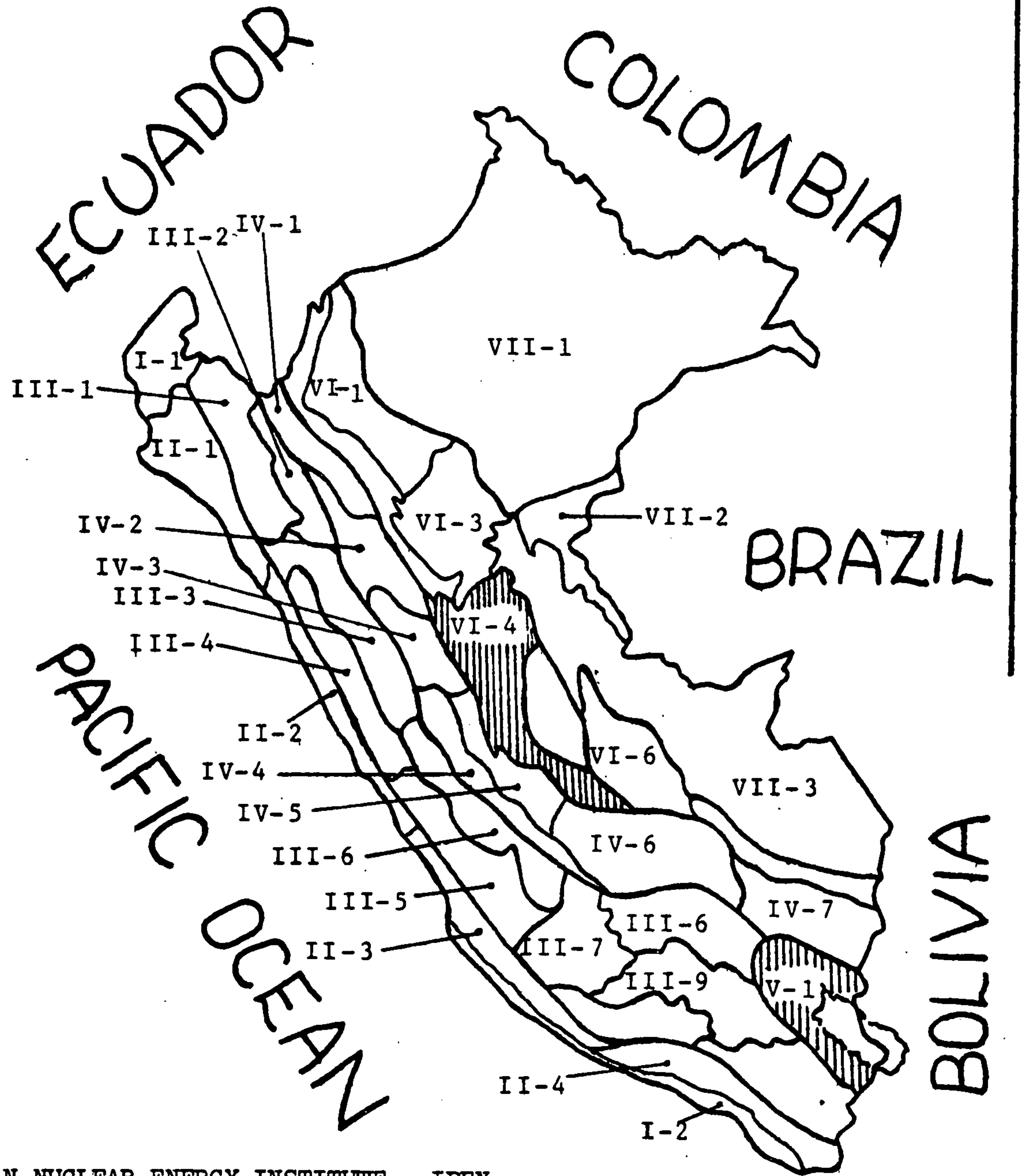
- Boring programs to locate favorable strata and possible beds, including radiometric soundings in selected test pits.

- Compilation of geological, radiometric and geochemical data in appropriate maps and reports.

- Preliminary evaluation of the geological potential of all discovered uranium deposits and previously known occurrences.

Although the Program II personnel will be primarily concerned with the two designated areas, the Program II Director and the other experts will provide advice, if so requested, on the exploration and exploitation of uranium in other Peruvian regions.

MAP-1



PERUVIAN NUCLEAR ENERGY INSTITUTE - IPEN

References

I, II, etc.: "Regional Uraniferous Geologic Environments"

II-1, II-2, etc.: "Uranium Prospecting Units"

Prospecting Units Selected
for the IPEN-UNDP Project

(2) Selected Areas

Priority areas for uranium prospecting under Program II were selected by Mission PER/38/06, as part of which an IAEA expert prepared a geologic-uraniferous sketch of the country. Two of the geologic units deemed to be of the first priority were selected for the purposes and objectives of this project. Factors taken into account in making the selection included the importance of each area's favorable geologic indicators, its support infrastructure and the variety of prospection methodologies that could be used.

The two selected areas are (see MAP 1):

- Prospecting Unit VI-4 -- Tingo María-Oxapampa-Satipo

  This unit predominantly contains Cretaceous and Tertiary continental sedimentary formations having lithological and structural characteristics regarded as indicative of good potential favorableness. It also includes a widespread intrusive body (San Ramón granite) with high radiometric readings and permeable levels containing remains of organic matter (carbonaceous tree trunks, fronds, etc.). The area exhibits intensive weathering. The principal physiographic features include a craggy Eastern front (1,500-2,000 m) which drops steeply toward low (1,000 m) mountain ranges and then becomes less rugged, gradually changing into level terrain toward the Northeast. The area shown in MAP 1 amounts to 41,000 square kilometers.

- Prospecting Unit V -- Puno

  This region consists of a wide variety of geologic units and chronostratigraphic locations. It contains six formations of Upper Cretaceous-Tertiary continental sedimentary rock whose uraniferous parameters merit interest. In addition, there are other favorable conditions, such as the presence of extrusive volcanic rocks (Tacaza, Sillapaca and Barroso Formations). The physiography of this region is typical of the Andean Plateau (4,000-m elevation), mildly tectonic, with folding of the Andean cycle and longitudinal faulting which creates localized basins filled with Quaternary sediments. The area shown in MAP 1 amounts to approximately 38,000 square kilometers.

The areas discussed above correspond to the geological units which have the highest potential for prospecting. For the purposes of implementing Program II, however, a total area of not more than 35,000 square kilometers will be defined for the first stages of field work. The tasks described in the plan of work will be carried out in this limited area only.

(3) Initial Reconnaissance Activities

- Sectors will be delimited in the (selected) priority zones, with a total area such as can be feasibly covered during the term of Program II.

  The boundaries of the sectors will be traced on the basis of a previous stage involving detailed uranium geology studies.

  The characteristics of the prospecting methodology most suitable to these sectors will be reiterated during this stage.

b. Meet the requirements of uranium prospecting systematically and intensively, using the latest available techniques and processes for prospection, evaluation and working of uranium-bearing minerals, particularly in sedimentary formations.

c. Enable an intensive prospection program to serve two purposes simultaneously:

   - Determine, as rapidly as possible, the level of uranium resources in preparation for the installation of nuclear power plants.

   - At the same time, create the technical and operational infrastructure necessary to accomplish all stages of the process, from the prospection, development and working of uranium deposits to the production of concentrates on a regular, economic basis.

PART II.E. OUTPUT

This activity will yield the following concrete results:

1. Systematic, intensive uranium prospecting, employing the latest available techniques and processes for prospecting, evaluating and working uranium-bearing minerals, particularly in scientifically selected sedimentary formations.

2. This intensive prospection program will also result simultaneously in an evaluation, within the shortest possible time, of the uranium resources in the selected areas.

3. A national infrastructure in the technology and operating capacity necessary to accomplish all stages of the project, starting with the prospection, development and working of uranium deposits,

4. An economically significant economic resource with a guaranteed demand (favoring economic growth).

5. Scientific and technological ability in the field, permitting sound, well-supported decisions to be made in the national interest.

PART II.F. ACTIVITIES

(1) Implementation Stages

According to the overall project for peaceful applications of nuclear energy (1977-1981), this program is scheduled to last five years. For execution purposes, however, Program II will have a term of three years. Upon completion of this stage, the development of the work and the results obtained in each aspect of the assistance effort will be analyzed, with special attention being devoted to the immediate prospects; if the results of the analysis are positive, then a possible second stage will be studied, establishing priorities in a new plan of work and budget.

This project review should be conducted six months before the completion of the first stage, in order to ensure continuity.

The available technical information is being analyzed, having already yielded a first, priority-ranked selection of mines, locations and areas that should be reevaluated and investigated in accordance with a working procedure designed to concretely define the significance of the discovered uranium traces. This task has been under way for the last two years and can be expected to pick up momentum as encouraging results are obtained, as has already been the case for a mine in the center of the country.

In regard to the preceding program, the need for a project for prospecting uranium in sedimentary rocks has been under consideration in the recent past. The scale of operation of this project will probably require national and international cooperation, and IPEN is expected to begin its first organizational stage before the end of this year.

Justification

The research already carried out indicates that uranium is present in Peru at sites ranging from high-temperature, deep, intermediate-age environments to lower-temperature, shallow, younger ones. These hydrothermal environments (hypothermal, mesothermal and epithermal) respectively correspond to the coastal strip and Western Andean slope, the summit of the Western and Eastern Andes, and the Eastern Andean slopes and Amazon Basin. Although the most extensive research efforts were devoted to the high- and medium-temperature locations, radioactive anomalies are more clearly evident in the epithermal locations and appear to increase as the temperature decreases toward the East. This suggests a probability that the largest concentrations of hydrothermal uranium will be discovered in surficial epithermal environments in the sectors of the country's Western Region, which are the least known and least investigated ones. Uranium-bearing mineralization can also be expected to occur in other sectors, but on a smaller scale.

The preceding conclusion reinforces IPEN's decision to implement a comprehensive Project for prospecting for uranium in sedimentary rocks. Continental and semi-continental sedimentary rocks (red strata) are extensively distributed in Peru, generally covering the Eastern strip, the Amazon Basin and portions of the Andean Plateau. In other parts of the world, the largest uranium deposits are found in this type of rock. Intensive investigation must be carried out in Peru to determine whether the characteristics of local rocks ranging in age from Mesozoic and Tertiary to Paleozoic are favorable for the occurrence of significant uranium-bearing deposits.

Planned Courses of Action

Given the situation discussed in the preceding paragraphs and taking into account the need to accelerate the process, the following courses of action have been established:

a. Conduct a reconnaissance survey to search for uranium minerals in a new area, to include a series of increasingly more complex and more costly measures or stages of work, each tending to increase the reliability of uranium potential estimates and reduce the risk of later investment for working them.

APPENDIX II

PROGRAM II: EVALUATION AND DEVELOPMENT OF URANIUM RESOURCES

PART II.D. BASES OF THE PROJECT

2. PROGRAM JUSTIFICATION

Background

Exploration for radioactive ores was begun in Peru in 1955. An intensive effort was undertaken during the first seven years of the present decade, aimed at investigating mixed metal ore deposits in the Coast and Sierra regions. This effort followed the orientation and methodology used elsewhere in the world at the time, also taking into account the fact that, in a mining country such as ours, some uranium concentration worthy of interest might be associated with mineralizations of base metals, particularly those of the veined type.

A large part of the principal metal ore deposits of the Higher Andes and Central Andes was covered, a task that was made easier by their moderate relief and easy accessibility. The Western Slope of the Andes received normal coverage, while the ore deposits in the Eastern Slope of the cordillera was less thoroughly investigated, because less information is available about it, its topography is very rugged and access to it is more difficult.

Although the effort was not comprehensive insofar as areal coverage and extension and intensification of the investigation in specific sites, numerous occurrences of uranium in association with other metals were discovered, including some which merited detailed attention. Nevertheless, none of the discovered traces of uranium was economically significant.

Given the country's wide variety of geological environments, the first step of this prospecting effort consists of a thorough examination of significant mines and ore samples and the execution of radiometric land profiles. These tasks are conducted in parallel with or followed by very limited studies, in favorable areas, of continental sedimentary rocks, structures, oil-bearing provinces (asphaltic and bituminous shales), intrusive igneous rocks, metamorphic rocks, lake basins, and pyroclastic volcanic materials. These studies are followed by attempts to start analytic studies of lateral secretion and hydrothermal zoning of the uranium. Although the results of this effort may seem to have been negative, they do furnish a panoramic view--as far as is known--of the distribution of uranium in the country and of what may be expected from future research. The basic data is contained in some 700 reports prepared by Peruvian personnel in cooperation with specialists from the Nuclear Power Commissions of the United States (primarily), West Germany and France.

Starting in 1963, the prospecting effort was severely cut back, to the extent that it was almost completely halted. Since that time it has been gradually increasing once more, though modestly, by means of the introduction of more expeditious methods such as aerial radiometric surveying and, lately, geochemical prospecting.

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PROJECT BUDGET -- UNDP CONTRIBUTION

PROGRAM I - INCORPORATION OF NUCLEAR ELECTRICITY

10	PROJECT PERSONNEL	TOTAL man-months	TOTAL $	1977 man-months	1977 $	1978 man-months	1978 $	1979 man-months	1979 $	1980 man-months	1980 $	1981 man-months	1981 $
11.	EXPERTS												
11.02	Power Plant Siting	4	16,000					4	16,000				
11.03	Call for Bids	4	16,000									4	16,000
11.04	Proposal Evaluation	4	16,000									4	16,000
11.05	Installation Inspection and Control	3	12,000									3	12,000
11.06	Training of Operators	3.5	14,000									3.5	14,000
11.99	Subtotal	18.5	74,000					4	16,000			14.5	58,000
30.	TRAINING		39,000						9,000		30,000		
99	TOTAL UNDP CONTRIBUTION		113,000						25,000		30,000		58,000

PART II.K. INSTITUTIONAL STRUCTURE

In regard to Nuclear Power, it is associated with:

- the Directorate General of Electricity,
- the National Energy Research Institute,
- and other specialized agencies in the energy sector.

PART II.L. PRIOR COMMITMENTS AND PREREQUISITES -- None.

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS

1. Technical Report Submittal Schedule

The implementing agency will prepare technical reports on the topic listed below, for submission to the Government according to the following schedule:

Partial reports every three months an expert remains in the country, by expert and by topic.

Final Report -- Upon completion of each expert's mission.

PART IV. BUDGET

2. Description of UNDP-Furnished Inputs

B. Assignment of International Personnel

	Place	Starting Date	Duration
Nuclear Power Plant Siting Expert - analysis of local conditions, preparation of local group	Lima	April 1979	4 man-months
Expert in the preparation of procedures for analysis of power plant types - call for bids, specifications, etc.	Lima	January 1981	4 man-months
Expert to provide advice on proposal evaluation, contracting problems, etc.	Lima	September 1981	4 man-months
Expert to provide advice on methodology and procedures for training the construction inspection and control technical group	Lima	September 1981	3 man-months
Expert in the organization of a power-plant operational personnel training system	Lima	August 1981	3.5 man-months

C. Subcontracts -- Not applicable.

D. Training Provisions

Nuclear Power Plant Siting Methodology Study	Argentina Canada France Spain	May 1979	5 man-months
Training in Nuclear Fuel Cycle Economy Analysis	England Argentina Spain France	June 1979	4 man-months
Nuclear Power Plant Engineering - Construction and Operation	Argentina Brazil Mexico Spain France Canada	March 1981	6 man-months (5) (Total 30 man-months)

E. Equipment and Supplies -- Not applicable.

F. Miscellaneous Expenses -- Not applicable.

PART II.C. INPUTS

1. Description of Government-Furnished Inputs

B. Assignment of Domestic Personnel

	Place	Starting Date	Duration
Chief Engineer, Nuclear Power Department, IPEN - Coordinates activities, expedites furnishing of information and assistance to the experts	Lima	January 1977	Entire Project
Three senior engineers specializing in nuclear power planning	Lima	January 1977	Entire Project
One engineer specializing in electronic facilities and equipment	Lima	January 1977	Entire Project
Auxiliary technical personnel - Draftsmen, secretaries	Lima	January 1977	Entire Project

NOTE: All local personnel will be employed at IPEN before the start of the Project.

D. Government-Furnished Buildings, Equipment and Supplies

Materials and Supplies	Place	Delivery Date	Cost (Soles)
Office, calculation and drafting supplies	Lima	As needed	300,000

Buildings and Equipment	Place	Delivery Date	Cost (Soles)
Existing IPEN buildings and offices	Lima	Existing	5,000,000
Typewriters and calculators	Lima	Existing	600,000
Office furniture	Lima	Existing	500,000

E. Miscellaneous Expenses

	Place	Starting Date	Cost
Group operating expenses (according to 1977-1981 Nuclear Plan)	Lima	From 1977 to 1981	12,700,000

(ii) Optimal mix of power plants using fossil fuels available in Peru.

(iii) Possible use of geothermal energy.

(iv) Optimization is understood to be in economic terms, taking into account the future growth of electricity consumption and the need for continuity in the supply of electricity, and favoring the use of Peruvian natural and human resources.

The investment model to be used for the electricity sector will be IAEA's WASP Program, which will be transferred to Peru at a later date. Using this model, as well as others that may result from revisions of it, Peruvian engineers will be able to periodically revise the long-term plans for expansion of the electricity generation systems.

The details of UNDP's activities are also contingent on the results obtained in the Nuclear Power Planning Study. Generally, however, their main objective is to achieve maximum participation of the local economy and technology in the installation and operation of the power plants.

PART II.F. ACTIVITIES

The two previous stages were defined in 1976 and 1977:

(1) Form a professional group sufficiently qualified to play an active role in the planning of nuclear electricity programs, by means of the participation of senior professionals from IPEN, the Directorate General of Electricity and the National Energy Research Institute in the IAEA Inter-Regional Courses on the Establishment and Execution of Nuclear Power Projects held in Karlsruhe (1975), Argonne (1976) and Saclay (1976).

(2) Nuclear Power Planning Study to be performed by IAEA specialists with the participation of Peruvian professionals specifically qualified for it.

A third stage still remains to be implemented before the First Nuclear Power Plant is installed. This stage will include all the detail studies and the difficult and complex procedures of the call for bids, selection of type of power plant, contract award, etc.

1979/1981 -- In this stage, the project contemplates the furnishing of UNDP-IAEA assistance through the appropriate training of Peruvian engineers and the timely advice of foreign experts in the following manner:

TRAINING	PLACE	DATE
Training of Peruvian specialists in Nuclear Power Power Plant Siting - Power Plant Engineering - Operation - Fuel Economy	Lima and Abroad	From 1979 to 1981
ADVISORY SERVICES		
Assistance by experts in Power Plant Planning - Feasibility - Siting - Management - Installation and Operation	Lima	From 1979 to 1981

APPENDIX I

PROGRAM I: PREPARATION FOR THE INCORPORATION OF NUCLEAR ELECTRICITY

PART II.D. BASES OF THE PROJECT

2. PROGRAM JUSTIFICATION

Peru is a rapidly developing country, with a great demand for energy. It possesses extensive potential hydroelectric resources which, however, lie in complex geographic settings, so that a relatively significant thermal generation capacity will apparently also be needed by the 1990s.

It is thus important to determine, as soon as possible, the most advisable share of nuclear energy in that additional thermal generation capacity, so that adequate preparation can be made, including all actions necessary to make it possible for nuclear integration to take place in a rational manner appropriate to the country's interests.

To this end, a group of professionals will be trained to be able to play an active role in the Planning, Selection and Operation of the First Nuclear Generating Plant, thus starting the Peruvian equipment program with a view to achieving a growing level of domestic participation. The formation of this group will enable Peru to reach independent decisions on what options are the most appropriate and advisable for the country while favoring the domestic technological and productive structure.

Worldwide experience shows that the process of preparing to achieve a domestic capability to participate in the field of nuclear power generation equipment requires much time. Consequently, it is advisable to start that process as soon as possible.

PART II.E. OUTPUT

A Nuclear Power Planning Study to be performed by IAEA in 1977 as a result of a request from the Government of Peru will provide the country with comprehensive basic information obtained by a neutral consultant using the most up-to-date techniques. The information, which will become available within a short time, will be used to develop not only Peru's nuclear program but also its entire energy planning activities.

The information from the IAEA study will enable Peru to proceed in detail with the process of integration of nuclear electricity, suitably advised by the international organizations (UNDP and IAEA) and thus avoiding political and economic commitments and technological dependence.

The Nuclear Power Planning Study will make it possible to determine the number of nuclear power plants, their optimum scale, and the installation dates (in the period 1985-2000) most advisable for bringing them into the country's power grid, taking into account the following considerations:

(i) Optimal utilization of hydroelectric resources.

APPENDICES

INTRODUCTION

The body of the overall project document covers general considerations pertaining to the following titles:

PART I. LEGAL CONTEXT

PART II. THE PROJECT

- PART II.A. DEVELOPMENT OBJECTIVES
- PART II.B. IMMEDIATE OBJECTIVES
- PART II.C. SPECIAL CONSIDERATIONS
- PART II.D. BASES OF THE PROJECT
  1. Activities included in the plan of operations.
- PART II.G. INPUTS
- PART II.H. PREPARATION OF THE FINAL PLAN OF WORK
- PART II.I. FRAMEWORK FOR EFFECTIVE PARTICIPATION OF DOMESTIC AND INTERNATIONAL PROJECT PERSONNEL
- PART II.K. INSTITUTIONAL STRUCTURE
- PART III.A. TRIPARTITE SUPERVISORY REVIEWS
- PART III.B. EVALUATION
- PART III.C. SPECIAL CONSIDERATIONS

RELATED ACTIVITIES

- PART IV. BUDGET

The following appendices cover the specific aspects of the relevant preceding titles and of the complementary titles which pertain to each of the five activities comprised in this project.

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PART IV. BUDGET

A. UNDP CONTRIBUTION (cont.)

		TOTAL man-months $	1977 man-months $	1978 man-months $	1979 man-months $	1980 man-months $	1981 man-months $
30.	TRAINING	247.000	54,000	40,000	68,000	66,000	19,000
40.	EQUIPMENT	357,000	65,000	76,000	78,000	107,000	31,000
50.	MISCELLANEOUS EXPENSES	16,000	1,000	5,000	5,000	5,000	
99.	TOTAL UNDP CONTRIBUTION	1,900,000	231,000	400,000	533,000	437,000	299,000

COUNTRY: PERU

PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PART IV. BUDGET

A. UNDP CONTRIBUTION (cont.)

		TOTAL		1977		1978		1979		1980		1981	
		man-months	$	man-months	$	man-months	$	man-months	$	man-months	$	man-months	$
11.14	Animal Husbandry and Nutrition	6	24,000							3	12,000	3	12,000
11.15	Animal Pathology	3	12,000							1	4,000	2	8,000
11.16	Plant Physiology	6	24,000							3	12,000	3	12,000
11.17	Genetic Improvement (Mutation Inducement)	6	24,000					2	8,000	2	8,000	2	8,000
11.18	Food and Feed Conservation	6	24,000							3	12,000	3	12,000
11.19	Forestry Research	3	12,000							1	4,000	2	8,000
11.20	Consultants	8	32,000					2	8,000	4	16,000	2	8,000
	<u>Radiation Protection and Safety</u>												
11.21	Teaching of Radiation Protection Courses	3	12,000					3	12,000				
11.22	Facilities and Licensing Control	9	36,000							6	24,000	3	12,000
11.99	Sub Total	295.5	1,218,000	24	103,200	63	259,200	89	363,200	61	251,200	58.5	241,200
13.	Administrative Support Personnel		30,000		6,000		6,000		6,000		6,000		6,000
15.	Official Travel		9,000		1,800		1,800		1,800		1,800		1,800
16.	Other Costs		12,000				6,000		6,000				
19.	Component Total		1,269,000		111,000		273,000		377,000		259,000		249,000
29.	SUBCONTRACTS		11,000				6,000		5,000				

COUNTRY: PERU

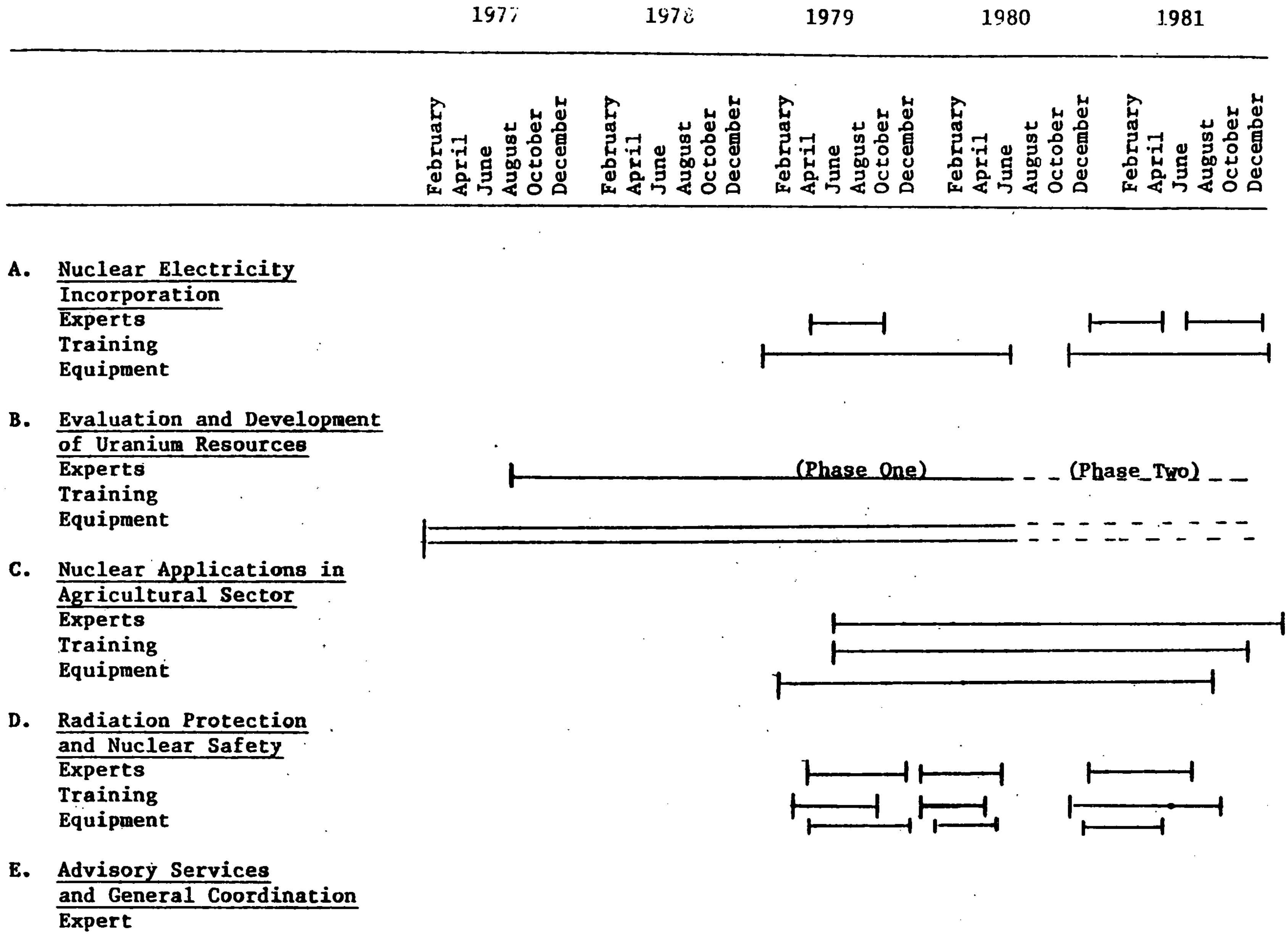
PROJECT No.: PER/76/002/A/01/18

TITLE: NUCLEAR ENERGY

PART IV. BUDGET

A. UNDP CONTRIBUTION

		TOTAL man-months	TOTAL $	1977 man-months	1977 $	1978 man-months	1978 $	1979 man-months	1979 $	1980 man-months	1980 $	1981 man-months	1981 $
10.	PROJECT PERSONNEL												
11.	EXPERTS												
11.01	Principal Technical Advisor	60	276,000	12	55,000	12	55,200	12	55,200	12	55,200	12	55,200
	Nuclear Electricity Incorporation												
11.02	Power Plant Siting	4	16,000					4	16,000				
11.03	Call for Bids	4	16,000									4	16,000
11.04	Evaluation of Proposals	4	16,000									4	16,000
11.05	Installation Inspection and Control	3	12,000									3	12,000
11.06	Training of Operators	3.5	14,000									3.5	14,000
	Evaluation of Uranium Resources												
11.07	Program II Director	36	144,000	6	24,000	12	48,000	12	48,000	6	24,000		
11.08	Sedimentation and Stratigraphy Geologist	27	108,000	3	12,000	12	48,000	12	48,000	6	24,000		
11.09	Prospecting Specialist	6	24,000	3	12,000	3	12,000						
11.10	Geochemist	24	96,000			12	48,000	12	48,000				
11.11	Economic Geologist	14	56,000					12	48,000	2	8,000		
11.12	Uranium Sedimentation Geologist	30	120,000			12	48,000	12	48,000	6	24,000		
	Nuclear Applications												
11.13	Program III Director. Course and Laboratory Organization, General Program Coordination	30	120,000					6	24,000	12	48,000	12	48,000



1977
1978
1979
1980
1981
February
April
June
August
October
December
A. Nuclear Electricity Incorporation
Experts
Training
Equipment
B. Evaluation and Development of Uranium Resources
Experts
Training
Equipment
(Phase One)
(Phase Two)
C. Nuclear Applications in Agricultural Sector
Experts
Training
Equipment
D. Radiation Protection and Nuclear Safety
Experts
Training
Equipment
E. Advisory Services and General Coordination
Expert

RELATED ACTIVITIES

As its National Prospection Plan is implemented, the Peruvian Nuclear Energy Institute may request UNDP and IAEA to divert all or part of its support to the Project to meet the needs of other research being conducted at the same time toward the same objective.

IPEN has been receiving continuous assistance in the form of equipment and materials from IAEA for use in activities related to prospecting, nuclear applications, and the like; this assistance may be placed at the disposal of the Project.

IPEN plans to train any Peruvian personnel it may contract domestically if possible, before considering sending them abroad for training.

former Atomic Energy Control Board. The agency has jurisdiction over all matters pertaining to the development and application of nuclear energy for peaceful purposes in the country and is responsible for planning, programming and developing the scientific and technological infrastructure in all areas in its purview.

The Peruvian Nuclear Energy Institute is guided by a Board of Directors which sets the policies of the institution. It is managed and administered by an Executive President [who combines the functions of Chairman of the Board and Chief Executive Officer] and an Executive Director [or General Manager]. The Board consists of eight members, namely:

- The Executive President [Chairman], representing the President of the Republic,
- the Vice President [Vice Chairman], representing the President of the Republic,
- one representative appointed by the Ministry of Economics and Finance,
- two representatives appointed by the Ministry of Health,
- one representative appointed by the Joint Command of the Armed Forces,
- one representative appointed by the National Board of Trustees of the Peruvian University, and
- one representative appointed by the Ministry of Energy and Mines.

The Project is located at the Peruvian Nuclear Energy Institute, which reports to the Ministry of Energy and Mines.

PART III.A. TRIPARTITE SUPERVISORY REVIEWS

The Project is subject to periodic review and revision in accordance with the policies and procedures established by UNDP for the monitoring of projects and program implementation and by the Republic of Peru's sectoral planning and control system.

PART III.B. EVALUATION

The Project will be subject to evaluation in accordance with the policies and procedures established by UNDP for the purpose. The organization, terms and conditions, and timing of evaluations will be decided in joint consultations between the Government, UNDP and the Implementing Agency, IAEA.

PART III.C. SPECIAL CONSIDERATIONS

The Government will take all necessary measures to ensure that all work performed under the scope of the Project will comply with the relevant IAEA safety standards. Reports of compliance with paragraphs 25(a), 26 and 27 of IAEA Document INFCIRC/18 will be submitted periodically to IAEA.

The Government agrees that none of the assistance it may receive by virtue of the Project will be used for any military purpose.

The Government of Peru is a signatory party to the Non-Proliferation Treaty.

Nuclear Physics Course
Nuclear Chemistry Course
and others.

Preparation, training and refresher programs to increase the knowledge of the professionals and technicians who play a direct role in the Plan--and therefore in the Project--is one of the priority objectives of the Nuclear Plan, which has made provision for the resources and means necessary to implement such courses. The Nuclear Plan has provided a total of S/. (Figure omitted in original) million (1976 prices) for these purposes.

2. Description of Inputs Furnished by UNDP

A. Prior Considerations

The contribution from UNDP, to be made available through the IAEA, the Implementing Agency, pertain to all components and will be disbursed in accordance with the usual procedures.

B. Assignment of International Personnel -- See the appendix corresponding to each program.

PART II.H. PREPARATION OF THE FINAL PLAN OF WORK

A "Detailed Plan of Work" for implementation of the Project will be prepared by the Principal Adviser and International Personnel Coordinator assigned to the Project, in consultation with the Project Director. The plan will be prepared at the beginning of the Project and then revised periodically. The Plan of Work agreed to will later be included in the Project Document as an Appendix and will be regarded as an integral part of that Document, not later than six months after the start of the Project. The periodic revisions will be drafted three months before (and after) the mid-Project revision and the Final Evaluation.

PART II.I. FRAMEWORK FOR EFFECTIVE PARTICIPATION OF DOMESTIC AND INTERNATIONAL PROJECT PERSONNEL

The work required to produce the results and achieve the immediate objectives of the Project will be performed jointly by the domestic and international personnel assigned to the Project. Their individual roles will be determined by their Chief through discussion and mutual agreement at the beginning of the Project, and will be recorded in a "framework" for effective participation of the Project's domestic and international personnel. This framework, which will constitute an appendix to the Project Document, may be revised periodically. The roles of both the domestic and the international personnel must always be in conformity with current guidelines and the specific purposes of the technical cooperation effort.

PART II.K. INSTITUTIONAL STRUCTURE

The Project will be managed by the Office of the President of the Peruvian Nuclear Energy Institute (IPEN), an agency established on 4 February 1975 by Decree-Law No. 21094 to regulate the Energy and Mines Sector, replacing the

b. Evaluation and development of uranium resources.

c. Radiation protection and nuclear safety.

d. General advisory services to the Government and IPEN, and coordination.

The appendices to this document contain detail information on the justification, expected output, included activities, estimated inputs and other factors pertaining to each subproject of each of the above-listed programs of this overall project.

PART II.E. OUTPUT -- See the appendix corresponding to each program.

PART II.F. ACTIVITIES -- See the appendix corresponding to each program.

PART II.G. INPUTS -- See the appendix corresponding to each program.

PART II.L. PREVIOUS COMMITMENTS AND REQUIREMENTS -- See the appendix corresponding to each program.

PART II.N. FUTURE UNDP COOPERATION -- See appendix titled "Uranium Resource Evaluation and Development Program".

PART III. SCHEDULE OF SUPERVISION, EVALUATION AND REPORTS -- See appendices for each program.

PART II.G. INPUTS

1. Description of Inputs Furnished by the Government

A. Financial Commitments

The State will provide the financial resources necessary to carry out the activities contemplated under the present Project. The estimated cost of these activities, as provided in the Nuclear Plan, First Stage, 1977-1981, amounts to a total of S/. (Figure omitted in original) in 1976 terms

B. Assignment of Domestic Personnel -- See the appendix for each program.

C. Training Funds

The Center for Advanced Nuclear Studies (Centro Superior de Estudios Nucleares--CSEN), a branch agency of IPEN, has scheduled training courses to be held from 1976 to 1981 for personnel contracted or brought into the project as a whole.

These courses will be taught by domestic and foreign teachers and experts and will cover the following areas:

Nuclear Engineering Course
Radiation Protection Course
Uranium Ore Prospection Technology Course
Radiation Employment Methodology Course

c. Enact the appropriate legislation and standards.

5. Technical Advisory Services to the Government of Peru and to IPEN, and General Coordination

a. Availing itself of the advice provided by the International Atomic Energy Agency Expert (PER/0/04), the Peruvian Government, acting through the Peruvian Nuclear Energy Institute (IPEN), has established a realistic, concrete plan whose first stage is scheduled to be implemented in the period 1976-1981.

b. It is essential for the Government and the Peruvian Nuclear Energy Institute to continue to make use of such technical advice during the difficult process of implementation of the plan, particularly in regard to the technical and scientific aspects pertaining to the tasks of research and development, personnel training, organization, execution planning, and the like.

c. The tasks involved in the Project will be coordinated at the same time.

PART II.C. SPECIAL CONSIDERATIONS

Not applicable.

PART II.D. BASES OF THE PROJECT

1. As is mentioned in the Nuclear Plan itself, its objective cannot be attained unless Peru can obtain the greatest possible amount of technical assistance and know-how through international cooperation (international organizations, bilateral agreements, etc.) as part of a well-planned and well-coordinated activity. Conditions must be such as to ensure that every step of such external assistance--no matter how small--will mean an actual increase in locally available knowledge, representing a gradual accumulation of information which, when applied to the country's own domestic experience, will make it possible to create a sound implementation capacity.

"Well-planned and well-coordinated activity" is understood to mean not only that appropriate international cooperation will be available at the proper moment, but also that a positive attitude will be ensured--on both the bilateral and the international organization level--with a view to supporting the Peruvian effort toward the peaceful use of nuclear energy, preventing duplication of effort and counterproductive actions.

The cooperation requested from UNDP-IAEA pertains to those tasks which most closely comply with the spirit and philosophy of the United Nations Development Programme, in that they have the greatest social and economic impact and capacity to develop scientific and technological knowledge so as to permit making decisions in the national interest. This plan of activities includes the following tasks:

a. Preparation for incorporation of nuclear electricity.

of the incorporation of nuclear electricity into the system, and its most suitable siting.

2. Evaluation and Development of Uranium-Bearing Resources

a. Contribute toward making the National Radioactive Resources Plan an effective means of implementing its extensive program of prospecting and studying in detail Peru's uranium resources, and of training its personnel in all modern techniques used in that kind of work.

b. Use modern prospecting techniques to investigate potential uranium resources in the designated areas, which cover a total of approximately 35,000 square kilometers.

c. Perform a technical and economic evaluation of all deposits of uranium-bearing ores and help to promote the recovery of uranium from copper and other ores already mined in the country.

d. Train Peruvian Nuclear Energy Institute (IPEN) personnel in modern uranium prospection techniques.

3. Nuclear Applications in the Agricultural Sector

a. Training of highly qualified personnel and intermediate supervisory personnel in the application of the nuclear sciences to agriculture and animal husbandry.

b. Determination of priority implementation areas, in which the application of nuclear sciences will have the greatest impact on the national economy and society.

c. Development of research programs in the areas selected in the preceding Section b.

d. Practical application of the results of the implemented programs and transfer to the productive sectors.

4. Radiation Protection and Nuclear Safety

a. By means of the necessary technical assistance and training, obtain a professional team with sufficient scientific and technical know-how to adequately draft the applicable standards and compliance guidelines, while ensuring the protection of the population and the environment from the effect of radiation.

b. Develop radiation protection technology, including training and development, implementation of personal dosimetry techniques, radiation protection technology, protection from radioactive aerosols, decontamination of equipment and materials, final management of redioactive residues, transportation and storage of irradiated fuel, etc., and procedures to be followed in the event of personal radiation exposure accidents.

Stage 1 - 1977-1981 -- Basic support preparation.

Stage 2 - 1981-1986 -- Obtaining of domestic experience and beginning of concrete realizations.

Stage 3 - 1985-2000(?) -- Development of nuclear electricity.

The first stage of the Plan (1977-1981) establishes a schedule of tasks designed so that Peru will have available, by 1981:

a. A significant professional cadre of nuclear specialists trained in the latest techniques and advances in the field. This group will constitute the foundation for the immediate activities, providing the Plan with its essential domestic character and nature.

b. A modern Nuclear Center, equipped with a research reactor and operating on a regular basis, run by Peruvian professionals.

c. A real evaluation of the country's potential uranium production, based on an intensive, systematic program of uranium prospecting.

d. A rational utilization of the possibilities offered for nuclear applications in health and agriculture.

e. An effective national authority which can guarantee to the country that the use of nuclear energy will not affect the population or the environment.

Five programs--each of which is divived into subprograms--have been defined in order to attain these goals; also, required investments of human and financial resources have been estimated for each of them.

Implementation of the Plan will require a substantial technical cooperation effort. In this regard, the Government has requested UNDP to provide advisory services in the planning and general execution of the Plan, technical and economic analysis of the nuclear electricity incorporation potential, and, most specifically, the uranium resource evaluation and development, agrigultural nuclear applications and radiological protection and nuclear safety programs. These activities together constitute this Project, designated PER/76/002 - Nuclear Energy.

PART II.B. IMMEDIATE OBJECTIVES

The immediate objectives of the Project's activities include:

1. Incorporation of Nuclear Electricity

   a. Establish a team of Peruvian engineers and scientists with sufficient know-how to play an effective role in the planning of nuclear electricity and to advise the Government's policymakers in a field which requires a significant national effort.

   b. To perform the necessary studies to allow determining, on technical and economic bases, the advisability, scheduling and characteristics future energy supply; therefore, the country must acquire sufficient scientific and technological skills to ensure that it will have autonomy of decision and a significant participation, tending to develop the national productive technical structure.

c.2 Develop the nuclear fuels industry so as to achieve self-sufficiency of supply to meet the future domestic demand in the field of nuclear electricity applications, as well as eventually to participate in supplying the world market for such fuels.

d. <u>Radioactive Mineral Resources Factor</u>

d.1 Intensify operations related to the prospection, exploitation, processing and refining of radioactive ores in domestic deposits, so as to provide the country with a significant productive capacity in this field.

d.2 Investigate all exported ores with a view to determining their radioactive material content, in order to obtain the highest possible total value from their sale.

e. <u>Training and Human Resources Factor</u>

e.1 Develop a high level of technical and scientific know-how in all aspects of the nuclear energy field, so as to have available a human resources infrastructure sufficiently skilled to conceive, draft, program, execute and control such nuclear plans as may be adopted by the Government.

e.2 Promote technical and scientific training, research and dissemination in nuclear energy utilization, incorporating its advances in the national developmental process.

f. <u>Human and Environmental Protection Factor</u>

f.1 Ensure adequate protection of the population and environment against the risks associated with the use of ionizing radiation,

g. <u>Inter-Sector Coordination Factor</u>

g.1 Establish a program to ensure the significant, coordinated participation of all the country's productive sectors in the field of nuclear energy, guiding the process so as to guarantee the fulfillment of the national developmental objectives.

2. On the basis of the established general policy and objectives, the Government has drafted a concrete, realistic Plan specifying the goals and the means of attaining them and thus making it possible to achieve the objectives at reasonable cost and within a reasonable period.

The Plan covers the period from 1977 to 2000. In view of the present state of development of nuclear energy in Peru, however, it was deemed advisable to divide the Plan in several successive stages, to wit:

PART I. LEGAL CONTEXT

1. This Project Document will be the instrument (hereinafter called the Operations Plan) referred to in Article 1, Paragraph 2 of the Agreement Between the Government of Peru and the United Nations Special Fund signed by both parties on 19 January 1960. The Project to which it refers is executed within the scope of Peruvian Decree-Law No. 18742, on International Technical Cooperation in the Republic of Peru, and its implementing regulations.

PART II. THE PROJECT

PART II.A. DEVELOPMENT OBJECTIVES

1. The Government of Peru's 1975/1978 Sectoral Development Plan states that "Nuclear science and nuclear energy will be intensively promoted, together with the utilization of nuclear energy and techniques in those fields where their application will contribute to national development."

An overall policy capable of covering the remainder of this century has been established under this criterion, with the following objectives:

a. National Development Factor

a.1 Develop a scientific/technological structure of sufficient capacity to ensure an adequate response to requirements arising from the integration of Nuclear Energy to the country's development, tending to keeping the nation up to date insofar as the knowledge and applications of the nuclear sciences.

b. Socioeconomic Factor

b.1 Enable nuclear science and technology innovations and developments of interest to Peru to be transferred to the appropriate socioeconomic sectors.

b.2 Develop an integrated nuclear industry, with a view to:

- Diversifying energy resources.
- Creating new sources of significant economic resources.
- Promoting significant scientific/technological and industrial progress having a positive economic and social impact by virtue of its high technology level and aggregate value.

c. Energy Resources Factor

c.1 In spite of the fact that Peru possesses significant hydroelectric resources, the expected long-term increase in the demand for energy will require a large addition of thermal generation capacity after 1990, to be implemented in accordance with whatever national energy policy may be in effect at that time. Nuclear power must play an extremely important role in that

UNITED NATIONS DEVELOPMENT PROGRAMME

GOVERNMENT OF PERU PROJECT

Project Document

TITLE: NUCLEAR ENERGY

NUMBER: PER/76/002/A/01/18 Duration: 60 months

PRIMARY OBJECTIVE:

SECONDARY OBJECTIVE:

SECTOR: Energy Natural Resources - 50

SUBSECTOR: Energy and Mines Fuel and Energy - 5020

IMPLEMENTING GOVERNMENT AGENCY: PERUVIAN NUCLEAR ENERGY INSTITUTE (IPEN)

IMPLEMENTING AGENCY: INTERNATIONAL ATOMIC ENERGY AGENCY (IAEA)

STARTING DATE: 1 January 1977

GOVERNMENT CONTRIBUTION: (in cash) UNDP CONTRIBUTION: US$ 1,900,000

APPROVED:

______________________________ Date: ______________________
For the Government (signature)

______________________________ Date: ______________________
For the Implementing Agency (signature)

______________________________ Date: ______________________
For UNDP (signature)

ATTACHMENT 2 TO ANNEX 6

PER/76/002/A/01/18

UNITED NATIONS DEVELOPMENT PROGRAM

GOVERNMENT OF PERU PROJECT
MINISTRY OF MINES AND ENERGY

PROJECT DOCUMENT
NUCLEAR ENERGY
(OPERATIONS PLAN)

Duration: 60 months
UNDP Contribution: $1,900,000

Within this concept a strategy was designed to achieve long-range objectives. This strategy was planned in three phases, to be executed successively, and which could accomplish significant results before the end of the century. On the basis of the above mentioned concepts a plan for the first phase has been worked out to be executed within the medium-term (1976-1981) as presented in this document.

Lima, June 1976

issues licenses following verification of adherence to these rules.

Following the security report on the uranium production plants, the research reactor and peripheral laboratories, the facilities for the sealed sources, the irradiation plant, and all laboratories, a license will be issued.

All users of radioactive material and the nuclear reactor must also be licensed.

Though the technical and scientific tasks related to radiological protection and nuclear security are included in Program IV, it is necessary to create a collegial corporation that will assure the ruling and controlling authority at the highest level with complete liberty to set and enforce standards.

This corporation will be established as soon as possible and will work directly with the president of PINE.

SUB-PROGRAM 4 - INTERNATIONAL COOPERATION

It has been agreed that this Plan is subject to the technical aid and "know how" which foreign assistance will offer.

The planning, coordination, and procurement of this assistance within the limits of the Plan and in agreement with the policy and arrangements settled by the corresponding agency will result in effective action to place Peru as an active participant in nuclear-related international organizations to:

a. Gain for Peru the most and best technical assistance

b. Protect local, regional, and group interests across other geographical or sectorial positions

c. Establish a positive image of the level of development reached by Peru

d. Coordinate nuclear technical assistance with the national foreign policy (PINE - FFRR - PNI)

e. Coordinate the procurement of technical assistance and nuclear information to maximize its use within the Plan, and to control and evaluate the results obtained, reporting to the managing sectors.

This management and control activity within the Plan will be centered in the Bureau of International Relations, and for that purpose the above mentioned Bureau will be appropriately organized.

SUB-PROGRAM 5 - LEGAL ADVICE AND LEGISLATION

Development of the Plan must reach as soon as possible its authorized level, establishing responsibilities and jurisdictions.

- PROGRAM V -

MANAGEMENT, ADMINISTRATION, AND INFRASTRUCTURE

OBJECTIVES

To establish the conditions that will permit development of the Plan by means of appropriate direction and supervision, flexible and efficient management, and effective functional support.

STRUCTURE OF THE PROGRAM

Management
Administration
National Authority of Radiological Protection and Nuclear Security
International Cooperation
Legal Advice and Legislation

FORMS OF ACTION

For every sub-program, the following forms of action have been established.

SUB-PROGRAM 1 - MANAGEMENT

Though PINE has been organized to develop a primary nuclear activity within a specified financial plan and with limited means, it must adopt the appropriate structure and executive capacity to quickly and systematically achieve the objectives outlined in the Plan.

It will be the responsibility of PINE president to

a. Organize and control the Institute so as to shape it to the conditions and requirements outlined in the Plan.

b. Propose an organization that will best insure fulfillment of the Plan.

c. Implement the proposed organization as soon as possible (by the first semester of 1977) to accelerate development of the Plan.

SUB-PROGRAM 2 - ADMINISTRATION

Significant changes in the investment budget and operational expenses for the new Plan and the financial and operational complexity of its development and equipment requirements urgently necessitate organization of the administrative agency and adaptation of it to the conditions and magnitude of the Plan.

Studies undertaken in 1976 indicated the best organization and systems to obtain a rational and efficient administration of the Plan.

SUB-PROGRAM 3 - NATIONAL AUTHORITY FOR NUCLEAR SECURITY AND RADIOLOGICAL PROTECTION

PINE, defined as the National Authority, sets the rules (see Program IV) that must be fulfilled in the building and operation of nuclear installations. PINE

SUB-PROGRAM 2 - OPERATIONAL SECURITY AND PROTECTION

a. Fulfillment of nuclear security and radiological protection rules is a crucial function of PINE. Schduled and unscheduled inspections must be carried out at every installation included under the Plan and at any other institution employing radiation. Statistics on all radioactive material in the country must be centralized. In every case PINE, in agreement with the international agreement signed, will apply and enforce these security measures.

b. Protection measures will be instituted and enforced in every nuclear operating installation including those that employ radioactive sources or material. To that end, standards for protection during operations and for the surrounding environment must be defined.

SUB-PROGRAM 3 - COMPLEMENTARY TECHNICAL AND SCIENTIFIC ACTIVITIES AND ACTIONS

The effective fulfillment of the Program requires the following activities:

1. Personnel dosimetry
2. Radiation protection technology
3. Material and equipment decontamination
4. Action in case of radiological accidents
5. Dosimetry and calibration of sources
6. Instrumentation and development of equipment and techniques
7. Updating and dissemination of knowledge regarding radiological protection methods and systems

- PROGRAM IV -

RADIOLOGICAL PROTECTION AND NUCLEAR SECURITY

OBJECTIVES

The continued implementation of the Nuclear Plan is possible if radiation effects are controlled. The most important of the provisions in the employment of nuclear energy regard security and protection. Between 1976 and 1981 we must:

a. Establish the National Authority, which will issue rules for the construction and operation of every nuclear plant (or facilities where radiation is used), authorize operations, and extend licenses.

b. Assure effective enforcement of the rules, carry out inspections, and oversee corrective actions where necessary.

c. Assure maintenance of effective operational security and protection during construction and operation of installations to protect the public and the environment.

d. Develop and apply personnel dosimetry techniques, radiation protection technology, techniques for decontamination of material and equipment, plans for final disposal of radioactive residues and for transportation and storage of irradiated combustibles, and be prepared to take action in the case of radiological accidents.

PROGRAM STRUCTURE

SUB-PROGRAM 1 - NUCLEAR RULES, REGULATIONS, AND LEGISLATION

The writing of nuclear and radiological rules and regulations to minimize risks and accidents.

SUB-PROGRAM 2 - OPERATIONAL SECURITY AND PROTECTION

Through qualified security officers, assurance of fulfillment of rules and regulations.

SUB-PROGRAM 3 - COMPLEMENTARY TECHNICAL AND SCIENTIFIC ACTIVITIES AND ACTIONS

Personnel dosimetry; radiation protection technology; decontamination in case of radiological accidents. Dosimetry and calibration of sources. Tools, equipment, and techniques. Updating and dissemination of knowledge. General management and coordination.

FORMS OF ACTION

SUB-PROGRAM 1 - NUCLEAR RULES, REGULATIONS, AND LEGISLATION

Includes the writing of nuclear and radiological security rules and regulations to minimize the risks associated with ionizing radiation and to reduce accidents.

The material means are already available to facilitate the development of this activity immediately and effectively, with specialization in the teaching of the use of isotopes and radiations and in organizing a postgraduate course on the use of isotopes and radiations within farming research.

The present laboratory of radioisotopes and the teaching programs in the field of nuclear applications techniques of the National Agrarian University (NAU, created by an agreement between the NAU and Commission for Control of Nuclear Energy under the auspices of the International Organization for Atomic Energy) will service as an initial nucleus of the projected pilot center.

This pilot centre will coordinate its activities through contracts or bilateral agreements with other universities and institutions involved in this field of activity. The pilot centre will provide these institutions its teaching and research services and use of its facilities within the pilot centre's capabilities and objectives.

In principle, these priority areas of action have been selected: soils and fertilizers, vegetable physiology, zootecnic and improved genetics. Research work has already been initiated in the first of these areas.

SUB-PROGRAM 4 - STUDY AND PROMOTION OF OTHER APPLICATIONS OF INTEREST IN THE NATIONAL ENVIRONMENT

To obtain this objective an interdisciplinary group will be formed, capable of carrying out the technical/economic analysis of the feasibility of the use of other nuclear applications (industry,mining, etc.) to improve and increase productivity and other ends.

SUB-PROGRAM 3 - NUCLEAR APPLICATIONS IN THE FARMING SECTOR

Priority aim: the practical projecting of the nuclear scientific application in this sector, with the object of achieving an increase in production as well as an improvement in the techniques employed.

SUB-PROGRAM 4 - A STUDY AND PROMOTION OF OTHER APPLICATIONS OF INTEREST TO THE NATIONAL ENVIRONMENT

A technical/economic analysis of the use of nuclear applications of interest and preparation for their immediate use or use at such a time when the projected facilities contained in Program I are available.

SUB-PROGRAM 5 - ADDITIONAL TECHNICAL SERVICES

The formation of a technological support infrastructure, especially in the electronics and the instrumental field which would facilitate on a national basis the advisory work and services for that complex instrumentation essential for these activities

GENERAL DIRECTION AND COORDINATION

The Plan contemplates the creation of a nuclear medicine and biological pilot unit attached to PINE where new techniques, procedures, and clinical applications will be developed. The results of this research will be available to other institutions for the development of nuclear biological and medical techniques in the whole of the country and will significantly assist achievement of this objective.

SUB-PROGRAM 2 - BIO-MEDICAL APPLICATIONS

As indicated, the intention is to create nuclear medical and biological pilot units that would depend directly on PINE and be located in a medical hospital center. New techniques and procedures would be developed or existing ones adapted, employing marked products from the PINE laboratories. Clinical and therapeutic applications will be developed and fundamental research will be carried out with special emphasis on inherent problems of our environment. Advice and support will be offered to other institutions for the development of nuclear biological and medical techniques, in Lima as well as in other regions of the country,naturally exercising due and necessary control of same.

EXPANSION PROCESS

In 1977 the reconditioning for diagnostic and medical research of the nuclear medical unit of the National Institute of Neoplastic Nurses (PINE) was initiated. Simultaneously, initial construction will take place in some of the present headquarters of PINE. Then will begin construction of the field installations in the areas of the new headquarters of PINE.

SUB-PROGRAM 3 - NUCLEAR APPLICATIONS IN THE FARMING SECTOR

This sub-program outlines plans for construction of a nuclear science application pilot centre in the farming sector.

- PROGRAM III -

NUCLEAR APPLICATIONS

OBJECTIVES

To promote the use of radioisotopes and radiations for those applications of a social/economic interest and the regular production of radioactive material.

Of the numerous applications which are offered by the peaceful use of nuclear energy, it has been considered convenient to emphasize those with the greatest economic and social benefit, particularly medical and agricultural applications.

For both applications it is possible to realize an immediate increase and improvement without necessarily waiting for the installation of the Nuclear Centre or extraordinary resources or means. Through a well-planned and co-ordinated action between PINE and institutes, universities, and private centers, the following can be obtained: detailed and exact information on the process and any discoveries made in this field; promotion and support for the use of such results of special interest in the field of health and the economy of the country.

SUB-PROGRAM 1 - RADIOACTIVE MATERIAL

Up to the present time all the radionuclides have been imported; they are split and distributed in PINE. After the installation of the reactor in the Nuclear Centre, primary isotopes will be produced in Peru and simultaneously:

- The lines of production of marked components will be enlarged principally with I-125, Cr-51, and Tc-99 in connection with medical and biological applications and with P-32 for agricultural and biological applications. It is therefore somewhat premature to sustain the synthesis with the C-14 and H-3.

- The techniques will be made known in detail to those working in the various fields of application.

At present radioactive material is supplied to 20 hospital and university institutions. However, the use of radioactive material is low and limited nearly exclusively to the city of Lima. This is not in keeping with the population distribution of the country nor the possibilities and benefits offered by radiation.

The main reason for this unfavorable situation is a lack of continuous and well-planned action, of information, and of the promotion of the use of radiation, mainly in medicine. It is these problems the Plan is intended to solve.

SUB-PROGRAM 2 - BIO-MEDICAL APPLICATIONS

To attain detailed and precise information on the scientific progress achieved in this field within the framework of an equal economic and social as well as regional distribution.

SUB-PROGRAM 5 - COMPLEMENTARY TECHNICAL SERVICES

Through management and guidance of the program, laboratories, tools, and electronics and provision of logistical support, etc., support will be given to the scientific and technological development of all phases.

FOREIGN TECHNICAL ASSISTANCE - UNDP-IAEO

The planning and programming between the PINE and UNDP has been coordinated in detail, so that the contribution of IAEO will be totally incorporated in the provisions of the Peruvian Nuclear Plan (Program II).

The most significant contributions are: scholarships - US$168,000; experts-US$608,000; equipment-US$150,000; with a total estimated amount of US$926,000. (S/.60'109,000.00 at S/.65.00 to US$1.00.)

In addition, there is the possibility of negotiating and obtaining, on a yearly basis, limited technical assistance within the framework of the OIEA regular program, the details of which are discussed yearly with that organization.

BILATERAL TECHNICAL ASSISTANCE

Acting within the requirements of the Nuclear Plan, PINE will request bilateral technical assistance yearly from the countries with which Peru has signed nuclear agreements. The purpose is to shape, in detail, this yearly cooperation (scholarships, technicians, equipment, etc.) through Protocols of Immediate Action to be signed by PINE and the nuclear organization of each country. Such actions will be coordinated with the Ministries of Energy and Mines and Foreign Affairs and the National Institute of Planning.

In this context, the action of PINE will be oriented with priority to the following countries: Argentina, Brazil, Mexico, France, England, Spain, Belgium, Holland, Federal Germany, Sweden, Denmark, Italy, Canada, USA, India and Japan.

for uranium prospecting in Peru be best pursued through the United Nations Development Program with the International Atomic Energy Organization (OIEA) as the executive organization. Such an international cooperative system better adjusts to the conditions and purposes of the plan.

With international cooperation and advice (UNDP, IAEO), six sedimentary areas already selected in preliminary studies, as well as other areas of interest in Peruvian territory, will be surveyed. Later, in the chosen areas, the systematic tasks of prospecting and evaluation will be concentrated for five years (Plan UNDP-IAEO). The other areas will be prospected from 1981 onwards, or simultaneous prospecting might be done according to the possibilities of national or foreign resources.

SUB-PROGRAM 2 - EXPLORATION OF FILONIAN TYPE INDICATIONS

Systematic investigations for uranium evidence in new places and in those already identified are planned, while developing possibilities of recovering uranium from other minerals.

Available information has permitted the selection of mines, sites, and areas, with indications of priorities for a reevaluation and prospecting. This task has been undertaken in a limited way for the last two years and will grow when new and encouraging results are obtained, such as those in the central area of the country.

With improved technology and mine investigation, the actual work will be in- ...ified, simultaneously deepening the investigation of those areas showing ...d with other important basic minerals.

...RAM 3 - EVALUATION AND DEVELOPMENT OF URANIUM FIELDS

This entails establishing geological and mining tasks to evaluate and develop the uranium indications and the necessary standards for their exploitation.

The search for uranium in a new area (as in oil prospecting) normally includes a series of work phases, each time more complex and expensive as each phase tends to give more assurance to calculating the reserves and to reducing the risks of further investment and exploitation. Definition of the reserves is the most difficult phase of the process.

The scientific capacity for evaluating the uranium reserves will be augmented as much as possible, permitting proper decisions in the national interest.

SUB-PROGRAM 4 - PROCESSING AND CONCENTRATION OF URANIUM MINERALS

As it is necessary to progressively prepare for installation of the various phases of the nuclear fuel cycle, an important economic and political strategy in energy independence, a pilot plant at the laboratory level that can be technically and economically adapted to local conditions will be investigated and developed. In addition, studies will be made, incorporating information on national development and experiences, allowing us to cope with the phases of refining and concentrating nuclear minerals as soon as the first economically exploitable uranium field begins producing.

Therefore, keeping in mind the need to accelerate uranium prospecting, the following plan of action is to be followed:

STRUCTURE OF THE PROGRAM

SUB-PROGRAM 1 - SYSTEMATIC PROSPECTING IN SEDIMENTARY AREAS

Many sedimentary areas show essentially favorable geological characteristics. Those most promising areas must be scientifically selected for systematic prospecting.

SUB-PROGRAM 2 - EXPLORATION OF FILONIAN TYPE OF INDICATIONS

Efforts must be intensified to locate uranium in new as well as existing areas, and methods developed to recover uranium from other minerals.

SUB-PROGRAM III - EVALUATION AND DEVELOPMENT OF URANIUM FIELDS

Necessary standards for evaluating and developing uranium resources must be established.

SUB-PROGRAM 4 - PROCESSING AND CONCENTRATION OF URANIUM MINERALS

In order to investigate those uranium processes most technically and economically feasible for local use, a pilot plant at the laboratory level must be developed.

SUB-PROGRAM 5 - COMPLEMENTARY TECHNICAL SERVICES

This includes management and guidance of the program, acquisition of laboratories, tools, and electronics, development of logistic support, etc.

PLAN OF ACTION

The following plan of action has been established for each sub-program:

SUB-PROGRAM 1 - SYSTEMATIC PROSPECTING OF SEDIMENTARY AREAS

Sedimentary areas that show favorable geological characteristics have been chosen; priorities have been established for systematic prospecting. A preliminary exploration project has been prepared, foreseeing a significant expansion of this activity, including establishing the necessary means and resources for its achievement. The project foresees:

a. Pursuing uranium prospecting in a systematic and intensive manner using the most modern techniques and processes for evaluating and exploiting uranium minerals, especially in sedimentary formations.

b. Simultaneously building the technological and operative infrastructure necessary to accomplish all stages of the process, from prospecting and exploitation to the regular and economic production of concentrates.

It is evident that an action of this nature requires significant collaboration and technical assistance from other countries.

While not excluding other possibilities, it is felt that this integral project

- PROGRAM II -

EVALUATION AND DEVELOPMENT OF URANIUM RESOURCES

OBJECTIVES

It is necessary to determine the reserves of uranium within Peru in hopes of diversifying energy sources and of generating possible exports. Uranium prospecting will be pursued in a systematic and intensive manner, using the most modern techniques and procedures. Peru must also be prepared to exploit discovered resources.

Geographical and geological conditions of the country indicate that approximately 15 years of work is required to acquire definite information on possible uranium deposits. What this plan foresees in the 1976-1981 period is to obtain guiding information, as significant as possible, to permit within a reasonable margin of error establishment of a policy regarding the internal supply of uranium. This should also indicate the place of Peru in supplying uranium to the world market.

This requirement, of great political and economic importance, demands special effort and planning to permit shortening the usual time required for this process. It is planned to achieve the following in the next five years:

a. Systematic prospecting in some sedimentary areas, which have not as yet been studied in Peru. Atthe same time, the necessary training, equipment, and organization will be acquired to carry on this type of prospecting and evaluation in all the areas of the country where uranium could possibly be found.

b. Exploration of indications of the filonian type, scientifically intensifying geological and mining investigations, and development of technical and economical possibilities to recover uranium from other minerals.

c. Investigation and development at the laboratory and plant level of the methods that can better be technically and economically adapted to local conditions to produce and process concentrates of uranium.

Analysis of the action undertaken to date determines that:

a. Uranium prospecting has not been continuous nor systematic. Thus, the uranium resources in our country with its peculiar geological and topographical characteristics remain undetermined.

b. In general, the geological formations in Peru are considered favorable to the existence of uranium deposits, as stated by the majority of experts who have worked in Peru.

c. Uranium prospecting in Peru, following the orientation proposed by the first mission of experts who operated in the country in 1955-1962, was chiefly focused on the filonian forms. Very little was done in exploring sedimentary formations, although actually this type of formation is now the center of interest in relation to prospecting for uranium nearly all over the world. Also, it is in this formation that the most important deposits in South America have been found (Sierra Pintada - Mendoza, Argentina).

So as to permit all phases of the process to be developed within the program activities, it has been decided that it is convenient to have within the program the following operational areas:

- Engineering services
- Auxiliary technical services

FOREIGN TECHNICAL ASSISTANCE - IAEO-UNDP

The planning and programming carried out between IPEN and IAEO has been carefully coordinated in such a way that the support of UNDP is fully included within the provision of the Nuclear Plan for Peru.

In addition, there is the possibility of obtaining limited technical assistance annually within the framework of the regular program of the IAEO, details of which are discussed annually with that body.

BILATERAL TECHNICAL ASSISTANCE

Acting within the requirements of the Nuclear Plan, PINE will annually request bilateral technical assistance in nuclear energy. Cooperation is to be assured through annual action (training, technical assistance, equipment, etc.), according to the Immediate Action Protocol to be signed by PINE with the respective nuclear body of each country and coordinated with the Ministry of Mines and Energy - Foreign Affairs and the National Institute of Planning.

Support for the Nuclear Centre

Several foreign proposals for the design, construction, and equipping of the Nuclear Centre foresee including the provision of technical assistance and experts.

Experts	108 m/h	$228,000.
Fellowships	312 m/h	600,000.
Total		$828,000.

Other courses, conferences, and meetings of interest

It is foreseen that there will be courses, lectures, and roundtable meetings on different subjects related to the peaceful application of nuclear energy.

Technical assistance from abroad

Within the strategy mentioned in the formulation of the Plan, a program has been designed including foreign assistance of experts, scholarships, and equipment to be provided by the country supplying the Nuclear Centre in conjunction with the technical assistance of the OIEA.

There are other types of complementary assistance which will comprise financing, training, facilities, and custom tax exemption on patents, subsidies, and donations. This type of assistance and cooperation, even if not included in the Plan, will be promoted bearing in mind national interest.

SUB-PROGRAM 3 - TRAINING FOR THE IMPLEMENTATION OF NUCLEAR POWER

The basis of this sub-program takes into account the Medium Range (1976-1981) Plan whose projection reaches long-range and comes within the framework of the global energy crisis and the future energy perspective of Peru.

NUCLEAR POWER

It is a well known fact that a country needs adequate electrical power in the areas of industrial development and in urban and rural zones in order to make possible its development and improve the status of the underpriviledged.

The program for the interconnection of the national electrical network is in the process of execution. The increase in the cost of hydrocarbon, as well as the cost of engineering construction, and the time required to put the important potential hydroelectric resource at the disposal of Peru indicate the necessity of a thermal complement, to be of relative significance in the 1990's. Therefore, it is important to determine as soon as possible the degree of nuclear participation in that thermal complement. This permits adequate preparation to make possible nuclear integration in a rational and convenient way, always in the best interest of the country.

Foreign Technical Assistance

Within the announced strategy in the formulation of the Plan, we have directed the program in the line of foreign cooperation in technical assistance, training, and equipment.

SUB-PROGRAM 4 - COMPLEMENTARY TECHNICAL SERVICES

General support for the program coordinates the action of the different sub-programs to obtain acommon objective, as well as implementation of services of a scientific and technical character necessary to support and facilitate the reaching of established goals.

SUB-PROGRAM 2 - TRAINING OF HUMAN RESOURCES

Personnel must begin training prior to their work as outlined in the Plan, with training to continue throughout the Plan. Not only personnel covered in the Plan must be trained, but also those whose research involves radiation.

The process within the plan foresees the following phases:

Coordination and support to the universities, training for universities
Selection and incorporation of personnel
Complementary training, adaptation of knowledge to conditions and medium in which activities will develop
Gaining experience, counsel, and corresponding documentary support
Scholarships abroad
Permanent updating of knowledge and of specialization

The specific training of personnel in subjects of nuclear science and technology is to be continuing. Constant change and progress in this field demand a framework which will allow a continuous and uninterrupted process of learning and updating of knowledge.

In this respect foreign technical assistance is a determining factor during all phases of the continuous process of training in the science and technology of nuclear energy. In order that this training will bring the desired results, it will be planned and carried out bearing in mind the requirements and needs arising from the Plan and the national interest.

TRAINING OF PERSONNEL

The Centre of Advanced Nuclear Studies (CSEN) of the Peruvian Institute of Nuclear Energy has as its goal to facilitate the process of training and updating the knowedge of all professionals that will be involved directly or indirectly in the Plan.

Bearing this in mind, an increase in its current activities is foreseen, upgrading it to a stage in accordance with the needs of the Plan. The curriculum of the Centre will be:

Postgraduate training and specialization course for professionals
Radiological protection
Provision for nuclear medicine
Methods for the use of radiations
Modern physics
Radiochemistry
Geology, prospecting and evaluation of uranium bearing resources
Technology for desalinization
Technology of materials
Instrumentation

Course on the method and application of the use of radioisotopes
A postgraduate course on the methodology and application of radioisotopes with the purpose of training professionals in the use of radioactive material.

Meteorological laboratory and tower that will permit recording and processing of meteorological data.

General workshop that is equipped for mechanical, electrical, and electronic repair and maintenance of equipment and installations.

Administration building and training quarters that will provide a base for the direction, organization, and support of the facilities for instruction and training of personnel both of the Centre and other authorized Institutes.

Auxiliary services at the Centre that will comprise vigilance service, emergency electric generators, drinking water supply, a plant for the treatment of sewerage, medical facilities, firefighting and garage facilities, cafeteria, kitchen, and other services.

The active Peruvian participation in the international order and within the framework of the postulates of the Peruvian Revolution shall promote the agreement and application of covenants which will favor the country and the region as a whole.

The programming for effective and rational use of the reactor is one of the fundamental aspects of the problem, which will be given the utmost attention prior to and during construction of the reactor. Accordingly, an interdisciplinarian group will be formed which will supervise the program prior to and during the reactor's operation.

Auxiliary and complementary buildings and installations

The execution of the plan demands an immediate increase in current activities in all executive bodies and in the direction of IPEN; therefore,it is necessary to allow its development within reasonable conditions of operations, bearing in mind that the new Centre will be operating in approximately five years.

According to this restrictive criteria, the following provisional expansions and complementary installations have been devised. These will be situated on land assigned by the Ministry of Energy and Mines, where the offices of the Peruvian Institute of Nuclear Energy are currently located. These other areas are the following:

Provisional Complementary Installations	Area-Sq. Meters
Nuclear Engineering Office, Central Planning	280
IPEN's Combustion	
IPEN's Laboratory for Radiological Protection	350
Laboratory for Nuclear Medicine in INFN	150
Locale and laboratories for the teaching of CSEN, Library, Documentation Centre	500
IPEN's Service Area	180
Offices of the Directorate of the Nuclear Centre Project	400
Equipment of the Office of the Directorate of the Nuclear Centre Project	
	1860

(d) Task IV: Construction, Equipping, and Commencement of Operation of the Nuclear Centre

Equipment for the first phase includes:

Pool-Type Reactor:
10 MW and Peripheral Circuits

Auxiliary Laboratories
Zero Power Reactor
Neutronographical Laboratory
Physics Laboratory
Physic-Chemical Analysis Laboratory
Chemistry Laboratory
Radiochemistry Laboratory
Auxillary Workshop
Others

Plant for the production of radioisotopes that will be dedicated in the first phase to the production of a range of radioisotopes and marked compounds, with additional facilities for teaching and laboratory research work.

Plant for the treatment of wastes that will be designed for the treatment of wastes of low and medium intensity for the first phase of the Nuclear Centre.

National Centre for Radiological Protection, in accordance with the OEIA recommendations, that will be designed to offer the following:

Personal dosimetries on a national level
Radiophysical health services
Air pollution monitoring
Pathological examinations
Emergency services
Training facilities
Gauging facilities
Assessment services for users

Plant for the production of combustible elements that will produce combustible elements of the type used in the 10 MW reactor (On the basis of enriched UF6). It is estimated that it will use 10 kilograms of uranium per annum.

Mineralogical Centre (geology and uranium prospecting) that will have installations and equipment sufficient to carry out the routine analysis of fissionable material up to a capacity for 100 samples. It should also include facilities for mineralogical research, examination of material, aerial-photography, and projection and transport equipment.

In this first phase it will be necessary to carry out a general survey of future possibilities in national industry and local labor. Such information should help in planning for participation by Peruvians in the design, engineering, construction, equipping, and supervising of this phase of the Nuclear Centre.

3. The Reactor

At this stage within the Centre, the reactor constitutes the fundamental and determining element in the overall activity. It is of the utmost importance that the reactor should be built and operated bearing in mind local conditions and needs.

The installation of a reactor that can be used in the production of radioisotopes for training of highly specialized personnel, for teaching of nuclear technology, and for serving as a tool of research and experiment for the universities, industry, and private and public services, will be without doubt the answer to a host of technological, scientific, and economical problems.

Among the reactors for research and training that are already installed in the world market, it is believed the Pool-Type reactor of 10 MWs is most suited to our multiple needs.

The installation of the reactor has been taken as the critical parameter for construction of the Centre, as the reactor is the Centre's most important and most technically and operationally complex element. It has thus been decided that:

> The building, commencement of operations, and regular operation of the reactor should not go beyond 1981. All scientific and technological personnel that will be in charge of its operation and maintenance should be trained simultaneously.

4. Implementation

(a) Task I: Study of the Locality

This comprises topographical surveys and seismic and geotechnical studies of the Huarangal site.

(b) Task II: Study of the Ecology

This comprises meteorological and radioambiental studies of the selected site and the surrounding area. Said radioambiental studies should continue for several years in order to evaluate the effects on the ecology in the area.

(c) Task III: Establishment of a Nuclear Security Commission

This Commission, with adequate assistance, should have sufficient competence and knowledge to establish security standards and regulations for the design, production, installation, and operation of the nuclear reactor and associated installations.

who have specialized abroad, but who cannot apply their knowledge for the benefit of the country due to the lack of an adequate scientific and technological base.

2. A Nuclear Centre reasonably planned, well executed, and above all properly conducted would allow:

   - developing installations and operational means to facilitate formation of the fundamentals in science and nuclear technology. This would, simultaneously, permit the adaptation of knowledge and experience acquired abroad to local conditions.

   - integrating a necessary core of scientists and technicians of different specialities who would contribute professionally to specific tasks related to nuclear energy.

   - encouraging the progress of overall activity in the scientific and technological field throughout the country as well as the training of youth in science.

   - promoting advancements in many other fields of science and technology, The multiplying effect of nuclear energy has been recognized nearly everywhere in the world.

   Finally, the construction and installation of the Nuclear Centre is indispensable to achieving the development of nuclear activity in Peru.

3. Therefore, within the objectives aiming toward rapid development of the scientific and technological base to meet the integrated expansion of nuclear activity, the Nuclear Centre constitutes a determining element of the operational possibilities indispensable for this development as well as for scientific and technological training.

b. <u>Construction and Equipping of the Nuclear Research Centre</u>

1. Locality

   The study of the locality in its first phase has already been carried out. Various favorable plant sites have been identified, among which within the corresponding established priorities, the locality of "Huarangal" in the Chillon River area has been selected.

   The choice of the locality is of great importance in the development and rational operation of the Centre. Considered were technical complexities associated with security and protection of people and with air pollution problems. Also considered were the special seismelogical conditions of the Lima area, as well as regulations regarding use of the land.

2. Composition

   For the period of the 1976-1981 Plan, it is intended to build the first phase installations on a forty hectare site. These installations are only a part of the successive phases that will make up the Nuclear Centre.

- PROGRAM I -

ESTABLISHMENT OF A SCIENTIFIC AND TECHNOLOGICAL BASE

OBJECTIVES

a. To create a base, the Nuclear Research Centre, which will allow for an important group of scientists and technicians trained in the country and abroad, to form a solid base for research and development in those nuclear areas with priority in Peru, making possible technology transfer to the appropriate, economical social sectors.

b. To make possible a rational and methodical techno-economic analysis which will permit the determination of the characteristics for and the date on which the first nuclear station could be incorporated into the national electric network.

STRUCTURE OF THE PROGRAM

SUB-PROGRAM 1 - OPERATIONAL FACILITIES

Design, construction, equipping, and operating of the Nuclear Research Centre.

SUB-PROGRAM 2 - TRAINING OF HUMAN RESOURCES

The incorporation and training of a basic group of professionals (carried out simultaneously to the construction of the Nuclear Centre).

SUB-PROGRAM 3 - PREPARING FOR NUCLEAR ELECTRIC INCORPORATION

Techno-economical definition of the timing and considerations in which the incorporation is to take place. Determines future concrete nuclear planning.

SUB-PROGRAM 4 - COMPLEMENTARY TECHNICAL SERVICES

Overall direction and coordination, engineering services, and technical aid.

EXECUTION

The following forms of action have been established for the execution of each of the sub-programs.

SUB-PROGRAM 1 - OPERATIONAL FACILITIES - NUCLEAR CENTRE

a. Scope

1. Lack of a Nuclear Centre limits the possibility of obtaining from national experience the ability to innovate in the scientific and/or technological fields directly connected with nuclear development, such as physics, nuclear engineering, electronics, chemistry, metallurgy, etc.

   In this respect the nation is losing a significant amount of intellectual competence from those who have been academically prepared, including those

- P R O G R A M S -

IN ORDER TO ACCOMPLISH THE OBJECTIVES FORESEEN IN THE MEDIUM-RANGE (1976-1981) PLAN (FIRST PHASE - PREPARATION OF THE FOUNDATIONS), THE OBJECTIVES AND THE FRAMEWORK OF EACH PROGRAM HAVE BEEN ESTABLISHED, INCLUDING THE APPROXIMATE ECONOMICAL COST, THE NECESSARY HUMAN RESOURCES INVOLVED, AND A PRELIMINARY ESTIMATE OF TECHNICAL ASSISTANCE, ALL OF WHICH ARE DETAILED FOR EACH PROGRAM AS FOLLOWS:

PROGRAM I:	ESTABLISHMENT OF A SCIENTIFIC AND TECHNOLOGICAL BASE
PROGRAM II:	EVALUATION AND DEVELOPMENT OF URANIUM RESOURCES
PROGRAM III:	NUCLEAR APPLICATIONS
PROGRAM IV:	RADIOLOGICAL PROTECTION AND NUCLEAR SECURITY
PROGRAM V:	ADMINISTRATION, MANAGEMENT, AND SUPPORT

It is following this concept that we should seek the transference of technology by way of treaties and agreements, thus increasing national competence in the nuclear field.

As regards the training program, the Peruvian Institute of Nuclear Energy will act as the promoter for the Peruvian Government among all areas that are interested in the application of nuclear techniques in their respective field of activities.

2.6 ELEMENT OF PROTECTION FROM CONTAMINATION

2.6.1 To insure against the possibility of air contamination giving the population adequate protection against the risks entailed in the use of ionized radiation.

Although nuclear energy does offer miltiple peaceful applications, it also represents a potential risk which has to be adequately controlled.

Such protection will be achieved with the aid of adequate regulations, including a national authority to oversee all nuclear activity. Peruvian professionals will be trained in radiological protection in order to guarantee security against pollution.

2.7 INTERSECTORAL ELEMENT

2.7.1 To establish a significant and coordinated participation of all sectors of national activity concerned with nuclear energy by way of guidelines guaranteeing the fulfillment of the objectives of national development.

2.8 ELEMENT OF INTERNATIONAL RELATIONS

2.8.1 To propose the transference of technology and the growth of national capacity in the nuclear field by way of treaties and international ageements, which will encourage the active participation of Peru within international organizations according to the postulates of the Peruvian Revolution. The worldwide progressive development of technology for the peaceful application of nuclear energy suggests that the practical orientation for the acquisition of knowledge in this field should be the transference of technology. It would not be convenient under present circumstances nor in the immediate future to tax our skills in the development of our own technology. Top priority should be given to the adaptation of the most advanced technology to the needs of national development.

The analysis of the "World Energy Perspectives" allows us to appreciate how important nuclear energy is for the development of a country and the advantages it offers vis a vis petroleum and coal as a source of energy.

The preliminary feasibility studies prior to a "nucleo-electric" plan currently being developed have been considered as a medium range objective. However, the projection and sequence of studies, work projects, and supplies, etc. derived from them necessarily will place them in the "long-range" plan according to what the national policy will be on this subject in the future.

The initial plase of this technological development is the objective of a medium range plan: the equipping of operational facilities for the production fuel for the 10MW experimental reactor at the Peruvian Nuclear Centre.

2.4 ELEMENT OF RADIOACTIVE MINING RESOURCES

2.4.1 To itensify mine exploration activities, mine development and exploitation, and refining of radioactive minerals with the intention of giving the country a significant production capacity in this field.

2.4.2 To investigate all mineral exports in order to determine the presence of radioactive properties for accurate aggregate value.

2.5 ELEMENT OF TRAINING AND HUMAN RESOURCES

2.5.1 To develop high scientific technological training at all levels in the field of nuclear energy, which will allow us to have a workforce sufficiently trained to conceive, design, program, execute, and control the nuclear plans decided on by the Government.

2.5.2 To promote the teaching, research, and diffusion of scientific and technological knowledge in the use of nuclear energy, incorporating its progress to the process of national development.

The training of Peruvian professionals in the field of nuclear science will take place in Peru and abroad on the basis of the "Centro Superior de Estudios Nucleares" (CSEN). Such action has been coordinated with the Peruvian University, which will be augmented when the Nuclear Centre of Peru comes into operation.

2.2 ECONOMIC AND SOCIAL ELEMENT

2.2.1 To make possible the transference of nuclear innovations and scientific and technological developments of interest to Peru to the appropriate economic and social areas.

2.2.2 To develop an integrated industry in the nuclear field with an ability to:

- achieve a diversification of energy resources;
- create new significant economical resources;
- promote an important step forward in the field of science, technology, and industry that will have a positive social and economic result due to its technological and aggregate values.

The "Transference of Nuclear Technology" can be defined as the introduction of new processes and products as well as the improvement of current products by the application of nuclear methods. These could take the following forms:

- The acquisition of Capital Stock and intermediate products in which national technology has been incorporated.
- Transference and registry of foreign trademarks regarding products and/or characteristics of processes.
- Nonpatented technical assistance or "know how" obtained from abroad.
- Foreign personnel whose experience and knowledge is used within the country.
- Training of Peruvian personnel in nuclear technology abroad by way of bilateral agreements or through the United Nations.
- Technical information through books, bulletins, periodicals and other publications in circulation that would be incorporated into the "Information Centre."

2.3 ELEMENT OF ENERGY RESOURCES

To establish a schedule for utilization of nuclear electric energy in the future that the country will need to satisfy the growing demand for electric energy.

INTRODUCTION

Nuclear energy destined for peaceful uses has vast areas of applications, among which special consideration should be given to the positive use in the fields of health and nutrition, in mining and industrial technology, as well as in the production of electric energy. All these applications have proven in recent years that the nations of the world can reach development and improved well-being through the use of nuclear energy.

The Peruvian Institute of Nuclear Energy was created by Decree 21094 on the 4th of February 1975 as a decentralized public institution within the area of the Ministry of Mines and Energy, with the purpose of "promoting, coordinating, and controlling the development of nuclear energy and its applications in the country." Thus a forward step was taken in the establishment of means and conditions that will make possible an effective participation in the evolutionary process of the science of nuclear technology, incorporating the innovations and advances achieved in this field for the benefit of national development and welfare.

With the above mentioned in mind, the necessary steps were taken in working out the long range strategies and policies in the field of nuclear energy. As a result of the analysis of the development of nuclear energy in Peru and the ensuing creation of the Peruvian Institute of Nuclear Energy with its objectives placing it within the scope of national development, consideration could be given to the situation of the country within this field not only because of its own needs but also in relation to other countries.

Within this concept, after setting the long-range objectives, a strategy was designed to achieve these objectives. The strategy was planned in three phases to be executed successively, realizing significant results before the end of the century. On the basis of the above mentioned concepts, a plan for the first phase has been worked out to be executed within the medium term (1976-81) as presented in this document.

Lima, June 1976

The scope of this global long-range policy is projected to the end of the century and its objectives are the following:

2.1 ELEMENT OF NATIONAL DEVELOPMENT

To develop a technological-scientific framework with the necessary capacity to assure a response to the needs of integrating nuclear energy into national development with the intent of not falling behind in the knowledge and application of nuclear science as regards other countries on the same level of development as ours and to achieve, as well, a reasonable technological independence.

ATTACHMENT 1 TO ANNEX 6

MINISTRY OF MINES AND ENERGY
PERUVIAN INSTITUTE OF NUCLEAR ENERGY

NUCLEAR PLAN FOR PERU

Medium Range (1977-82)

(FIRST PHASE)

SUMMARY

Next Steps

In view of the potential for uranium resources, within the next few years Peru should:

1. resolve current questions concerning uranium resources by establishing the quantity and quality of reserves in presently known promising areas;

2. undertake a broad-based effort to identify additional promising geological areas for future uranium ore investigation;

3. obtain an improved knowledge of potential uranium ore resources by obtaining the necessary modern laboratory equipment and facilities, and train personnel to analyze ore;

4. encourage private industry and investors to prove out uranium resources, and establish the required uranium mines and mills to exploit any economically recoverable reserves which may be found.

Nuclear Power Plant Program - The Government of Peru currently has no firm plans or projections for construction of nuclear power plants. However, Peruvian officials are now considering the possible construction of a nuclear power plant with a generating capacity of from 450 to 600 MW with construction starting in approximately 1995. Their current planning includes initiating activities to develop the necessry infrastructure, identification of specific program requirements and means to achieve them, education of the general public in favor of nuclear power, preparation of licensing regulations, creation of a nuclear regulatory commission, and evaluation and selection of a potential site using IAEA and U.S. siting criteria.

Peruvian officials are weighing technical, economic and political factors in detemining whether to proceed with their nuclear power plans. Prior to making a commitment to a nuclear power program, they will utilize cost effectiveness studies to determine whether their energy needs could potentially be met with increased use of hydropower or other lower cost energy alternatives. Peruvian officials have indicated that they would require foreign assistance to pursue a nuclear power program.

Uranium Resources - Uranium has been detected in a number of different places in Peru, but none of the occurrances has been of sufficient grade or size to warrant physical exploration. The best hope for finding economic workable deposits seems to lie in the little-known and unexplored eastern slope of Cordillera. In addition, uranium-bearing phosphatic rocks are present in northwestern Peru. Analyses show that the uranium content of phosphatic rocks is lower than that which has been exploited anywhere in the U.S. for fertilizer with uranium as a byproduct. However, the extent of the phosphate deposits has not been determined. Thus a sound forecast cannot be made without additional pertinent information. The prospects for finding and bringing into production an economic source for uranium by 1985 are slight, but a continuing search is warranted. By the year 2000, or sooner, the efforts should determine the availability of economically workable uranium deposits and may have lead to the production of economic sources of uranium.

To sharpen incentives for the private sector to explore, mine, refine, and market uranium and thorium, Peru has prepared and is reviewing a Decree-Law (see Attachment 3) which describes the incentives. However, the current status of this decree in Peru's legislative process is not known.

shielding, bricks, cement, construction and certain skilled laborers. Peru will also provide some of the project management staff. The Nuclear Center will produce, package and prepare for shipment purified radiosotopes for medicinal, industrial, agricultural and other uses, particularly for the Andean Common Market as well as for internal Peruvian use. A secondary objective of the nuclear center is to help train personnel required for a nuclear power program. This infrastructure could be in place if a decision is made to build a nuclear power plant in 1995.

The Center will consist of the following:

Reactor - A 10 megawatt swimming pool type reactor will provide the neutrons to transmute source elements into radioisotopes. It will be light water cooled and moderated with a neutron flux of 6×10^{14} neutrons per cm^2 per second and will use a fuel enriched reactor with 20 percent uranium-235. The first core will be fabricated in Argentina according to present plans. As Peru is in an active seismic region, the reactor will be conservatively designed for seismic loadings. Attention is being given to the preparation and enforcement to a quality assurance program.

Radioactive Waste Plant - Low-level radioactive waste from the site activities will be treated, stored, packaged and eventually disposed of from this facility. The use of the facility is not expected to produce significant qualities of high level radioactive waste.

Fuel Element Fabrication Facility - A fuel element fabrication facility is planned with the capability to supply fuel elements for the reactor. The estimated uranium content of these elements will be about 50 kilograms, having an enrichment of 20 percent uranium-235.

Other Facilities - The Center will have other facilities required in support of the radiosotope program and other nuclear energy activites: chemical processing for separating and purifying radioisotopes, the National Center for Radiological Protection for nuclear workers and members of the general public, the Mineralogical Center for Geology and Prospecting for Uranium, the Training Center for Personnel, and a Maintenance Department.

Peru received U.S. origin enriched uranium in 1978 to operate the zero power research reactor (RP-0) from the Argentina National Nuclear Energy Commission through a quadripartite agreement among the governments of Peru, Argentina, the U.S. and the International Atomic Energy Agency. Peruvian officials have indicated an interest in several areas of nuclear cooperation with the U.S. A draft copy of a model agreement for cooperation in the peaceful uses of nuclear energy with the U.S. has been provided to Peru. The draft model agreement reflects the criteria of the U.S. Nuclear Non-Proliferation Act of 1978. This agreement is being reviewed by IPEN.*

The Peruvian Institute of Nuclear Energy (IPEN) is located in Lima. Within this center are the offices of the key management staff, educational facilities including classrooms and experimental laboratories, the zero power (approximately 10 watts) research reactor and computer support. Students from the nearby Peruvian University may receive training in nuclear engineering at the Institute.

The research reactor (light water moderated) is housed in a concrete structure. Because of the seismic activity of the area, the facility was designed and built to accommodate expected seismic loadings. The reactor was designed in Argentina and built at IPEN by Peruvians in 5 months with the help of a small group provided by the government and Argentina. The growing interest in the use of U.S. nuclear codes and standards, as well as communications with the U.S. Nuclear Regulatory Commission, indicates Peruvian awareness of the need for disciplined engineering.

The Nuclear Center

Construction on a nuclear center at Huangaral, about 40 km. east of Lima has begun and is scheduled to be completed in about 41 months. Peruvian technicians are to be assisted with the design and construction by Argentinian specialists. Peru will furnish domestically available materials, such as lead

* U.S. Embassy in Lima Peru advised in January 1979 that negotiations have yet to be initiated.

STATUS AND PLANS OF NUCLEAR ENERGY IN PERU

Introduction

The government of Peru is giving deliberate consideration to the use of nuclear energy to meet its projected electricity requirements. It is presently considering the possible construction of an initial nuclear power plant with a generating capacity of from 450 to 600 megawatts electric with construction to be initiated about 1995. Attachment 1 provides a summary presentation of Peru's nuclear energy plans for the period from 1977-1982; Attachment 2 (The Project Document for Nuclear Energy: An Operations Plan) provides additional detail and describes the program from 1977-2000.

Plans are now being implemented to build the required infrastructure and key nuclear research and development facilities. This involves, for example, training of engineers, skilled technicians and project managers, as well as the preparation of necessary standards and regulations. A decision whether or not to proceed with a nuclear power program however will depend heavily upon the extent to which hydroelectricity can meet Peru's electrical energy requirements cheaply and efficiently.

An agreement for nuclear cooperation between Argentina and Peru is in effect under which Argentina has supplied a zero power research reactor to Peru for the Peruvian Institute of Nuclear Energy (IPEN) in Lima. In addition Argentina is providing an entire research complex scheduled for operation by the end of the calendar year 1982, which includes a 10 MW research reactor, a radioisotope facility, and facilities for administration, radiological health and safety, safeguards, physical security and to provide training for Peruvian nuclear technicians.

Peru has signed and ratified the Non-Proliferation Treaty and the Treaty of Tlatelolco. A safeguard agreement pursuant to the Treaty of Tlatelolco has been signed, but is not yet in force.

ANNEX-6

STATUS AND PLANS OF NUCLEAR ENERGY IN PERU

BY
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AND
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U.S. - PERU COOPERATIVE ENERGY ASSESSMENT

NOVEMBER, 1978

Recommendations

1. Hydropower should be emphasized in meeting the electrical energy demands in Peru since the potential is great, and the water controls required for hydroelectric generation can be utilized for meeting other needs for water.

2. Comprehensive-coordinated water resource planning and development should be accelerated in harmony with the directives to the Multisectorial Commission of the National Plan for the Water Resources Ordination. The United States should offer appropriate assistance to this program if the Peruvians seek such assistance.

3. The mini-hydropower program initiated by the Peruvian Institute of Investigation Technological Industrial should be accelerated to provide electricity to small communities in the rural areas of Peru not now served by electrical energy. Such a program should prove to be a catalyst in improving human conditions. It can also provide employment to those that are served from the units that are installed. The United States also should offer appropriate assistance to this program if the Peruvian's seek such assistance.

4. It is evident throughout Peru that the most difficult problem is financing of resource developments. This appears to be basic to all facets of the economy.

OBSERVATIONS AND RECOMMENDATIONS

Observations

1. Hydropower does not pollute the water or air. It provides clean energy. Often, the storage lakes and controlled river flows provide improved habitats for fish and wildlife.

2. Since most of the load requirements to the year 2000 are in western Peru, future developments will largely depend on diversions of water from the east slope of the Andes and from generation in the Amazon drainage area. Additional water and water regulation is needed for irrigation, municipal, and industrial purposes to meet the growing needs in western Peru as the population and economy continues to expand.

3. Emphasis on hydropower will save gas and oil supplies. This will help Peru maintain a favorable balance of trade, thus bolstering its financial and economic welfare.

4. Water diverted from the east to the west of Peru for hydropower must be coordinated with other uses, including irrigation, municipal, industrial and recreational needs. The objective is to promote multiple-purpose projects that yield the greatest overall benefits to Peru. This will expand the economic base and enhance the present and future welfare.

5. Expansion of the hydropower system, along with increasing the irrigation, municipal, and industrial water supplies, will accelerate the expansion of the transmission system, which will make it possible for dispersion and expansion of industrial and municipal growth. All of this will provide more jobs which in turn will create more demands for goods and services.

COORDINATION OF MULTIPLE PURPOSE PROJECTS

Peru is growing in population and economic activity particularly in the coastal portion where the water supply has been largely utilized by irrigation, municipal, industrial and power developments. The growing energy needs of the metropolitan area of Lima have required diversion of water from the east through development of the Mantaro hydroelectric project. Full development of this project from the present 342 MW capacity to 798 MW will not only be necessary to meet a portion of the growing hydropower needs but in meeting water requirements for other purposes.

The growth of population and related developments at Trujillo, Lima, Arequipa, and other places, for instance, indicate that projects initiated primarily for power can be of great benefit in these and other portions of western Peru when they are coordinated to meet the multiple uses of water.

Present observations and magnitudes of such problems emphasize the increasing importance that multiple-purpose water resource developments will have as the resources are more fully utilized. Requirements for quality and quantity, especially in such coastal areas as at Lima, are of great importance in present and future planning. Hydroprojects that supply energy and quality water for other uses must be given top priority for the economic well being of Peru

Table 11

THE PROJECTED COSTS OF HYDROPOWER*

(In Millions of Dollars-1977)

REGION	YEAR 1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	TOTALS
CENTRAL-NORTH												
Total power costs	133.19	143.89	209.72	312.53	332.17	373.39	283.84	197.50	80.95	92.29	69.82	2,229.29
Hydro % of total	61	64	71	87	75	77	100	100	100	100	100	83
Hydropower costs	81.30	91.88	149.53	270.58	247.49	287.97	283.84	197.50	80.95	92.29	69.82	1,853.15
SOUTHWEST												
Total power costs	34.05	29.47	44.44	44.95	61.48	57.96	60.09	29.95	20.87			383.26
Hydro % of total	54	75	95	100	100	100	100	100	100			93
Hydropower costs	18.54	22.23	42.02	44.95	61.48	57.96	60.09	29.95	20.87			358.09
SOUTHEAST												
Total power costs	17.05	33.99	30.41	3.69	5.42	6.17	5.24	5.70	6.61			114.28
Hydro % of total	82	100	100	100	100	100	100	100	100			97
Hydropower costs	14.06	33.99	30.41	3.69	5.42	6.17	5.24	5.70	6.61			111.29
SUMMARY												
Total power costs	184.29	207.35	284.57	361.17	399.07	437.52	349.17	233.15	108.43	92.29	69.82	2,726.83
Hydro % of total	62	71	78	88	79	80	100	100	100	100	100	85
Hydropower costs	113.90	148.10	221.96	319.22	314.39	352.10	349.17	233.15	108.43	92.29	69.82	2,322.53

* From "Plan De Electrificacion Nacional", Ministerio De Energia Y Mines. December 1977.

AVERAGE COST PER KILOWATT OF CAPACITY $\frac{\$2,322,530,000}{2,612,400} = \$889$ Say \$900 summarized in Table 11. This is for the specific power units as listed on Table 10. The average cost per kilowatt of capacity is $889, which includes transmission lines as well as the basic hydropower installations and related works. Apparently financing and related administrative costs are not included.

The following costs are based on $900/KW of estimated installed capacity, and on the growth of hydropower demands as summarized in Table 9.

ESTIMATED ELECTRICAL COSTS - 1977 THROUGH 2000
(Millions of Dollars-1977)

INCREMENT	Total Costs	Hydropower Costs
1977-1985	1,396	1,322
1985-1989	841	765
1989-1996	2,027	1,845
1996-2000	1,570	1,440
Totals	5,834	5,372
1985-2000	4,438	4,050

of the local people who would be served.

Such mini-hydroplants are expected to range from about 5 KW to 50 KW in capacity, with heads up to about 100 meters, utilizing PVC (plastic) pipe and other cost saving materials, and local labor for installation of the works under the guidance of technically trained students who are adept at surveying and construction.

The project, under the direction of Engineer Enrique Indacochea, is preparing handbooks for Pelton and Michell turbines of varying sizes adaptable for pre-manufacture which could be assembled and shipped from warehouses in Lima where the works would be manufactured.

Currently, the Institute is developing a pilot plant serving a rural community located near Canta about 100 KM northeast of Lima which involves a head of 56 meters, an alternator of 4 KVA, another alternator of 20 KVA, and a synchronous generator of about 15 KVA. One Pelton wheel and 2 Michell-Banki turbines are included. The small turbine is expected to be installed in August, 1978. The total cost (1977) is about 15,000,000 soles ($142,000).

Installations of mini-hydropower plants are expected to number 3000 by the year 2000. This would amount to a total capacity of 90,000 to 120,000 KW, with the plants ranging in size from 5 to 50 KW. It is estimated that 15,000 to 20,000 KW would be installed by 1985.

The Institute also is considering a small powerplant program ranging from 50 KW to 500 KW or thereabouts, with 40 M heads as a limit. Further in the future another program involving plants of 5 KW to 50 KW and low heads of 20 meters for adaption to jungle conditions is being considered.

Projected Costs of Hydropower

For the period 1977 through 1989, the Minister of Energy and Mines listed needed hydropower developments totalling 2,612.4 MW of increased capacity at a total cost estimated at $2,322.53 million dollars (1977) as

Table 10

PLANS FOR ADDITIONS TO
PRINCIPAL HYDROPOWER PLANTS - PERU.*

NORTH-CENTRAL REGION	MEGAWATTS	YEAR
Mantaro 4	114	1978
Mantaro 4,6,7	342	1979
Canon del Pato	50	1980
Restitucion	217	1982
Yuscay	2.5	1981
Poechos	11	1982
Curumuy	12	1983
Culqui	25	1983
Carhuaquero	75	1983
El Chorro	150	1985
Yuncan	126	1985
Sheque 1	150	1986
Sheque 2	150	1987
Sheque 3-4	300	1988
Olmos 1	151	1989
Olmos 2	212	1990
Subtotal	2,087.5	
SOUTHWEST REGION		
Charcani	135	1983
Lluta 1	137	1985
Lluta 2	137	1986
Subtotal	409	
SOUTHEAST REGION		
Machu Picchu	69.9	1981
Quishuarani	46	1987
Subtotal	115.9	
TOTAL	2,612.4	

* From "Plan De Electrificacion Nacional", Ministerio De Energia Y Mines. December 1977.

GRAFICO N° 5.08

hydropower plants have been shown on a map, copy included, titled "Plano De Ubicacion De Las Centrales De Generacion Y Sistemas Interconectados Proyectados" dated 7-12-1977.

In addition a list of the principal hydropower plants has been prepared and summarized in Table 10, which shows the additions by region, and the megawatts of capacity, and the year that the plant is expected to be in operation. Some of these projects, such as Mantaro 4, are under construction. These additions will provide 2,612 megawatts of additional power capacity by 1990. Presumably units not now scheduled may be added from time to time. The small mini-hydropower units are not included in these projections.

Plans for Mini-Hydropower Plants

Most of the installed capacity and energy in hydroelectric power systems in Peru is provided by relatively large powerplants serving the major cities and industries. The large plants provide maximum capacity and energy at practical costs which is distributed to load centers by transmission lines ranging from 10 KV to 220 KV capacity. Additional large powerplants and transmission lines are scheduled for construction to meet the growing loads found mainly at the larger cities west of the Andes, such as Lima, Chimbote and Trujillo.

In contrast, a large portion of Peru is not served by electric power in any form, including some communities up to 4,000 population, as well as the smaller isolated groups of dwellings throughout the country. Accordingly, the Institute of Industrial Technology Research and Technical Standards (ITINTEC) has underway a program to provide facilities and technology for design and installation of small hydroplants. The plants would be installed mainly at existing canals and diversion works where such installations would be practical, with approval and participation

Table 9

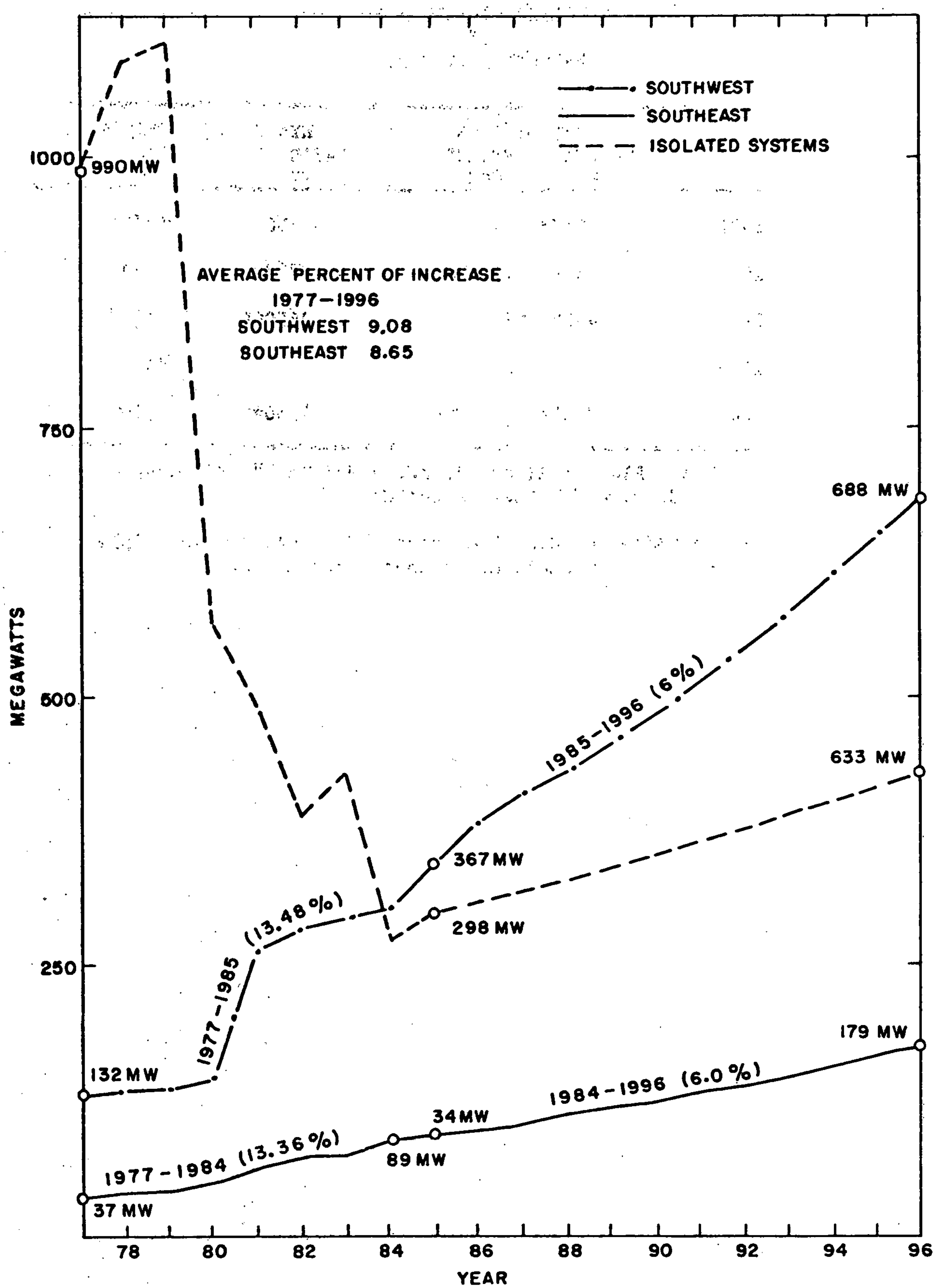
ELECTRICAL DEMANDS
of
PRINCIPAL SYSTEMS

YEAR	TOTAL DEMANDS		HYDROPOWER DEMANDS	
	CAPACITY MW*	ENERGY GWH	CAPACITY MW	ENERGY GWH
1977	1817*	9493*	1330.5*	5825*
1985	3368*	19106*	2800**	16500**
1989	4303*	24477*	3650**	22000**
1996	6555*	37840*	5700**	35000**
2000	8300**	48000**	7300**	45000**

* From "Plan De Electrificacion Nacional", Ministerio De Energia Y Minas. December 1977.

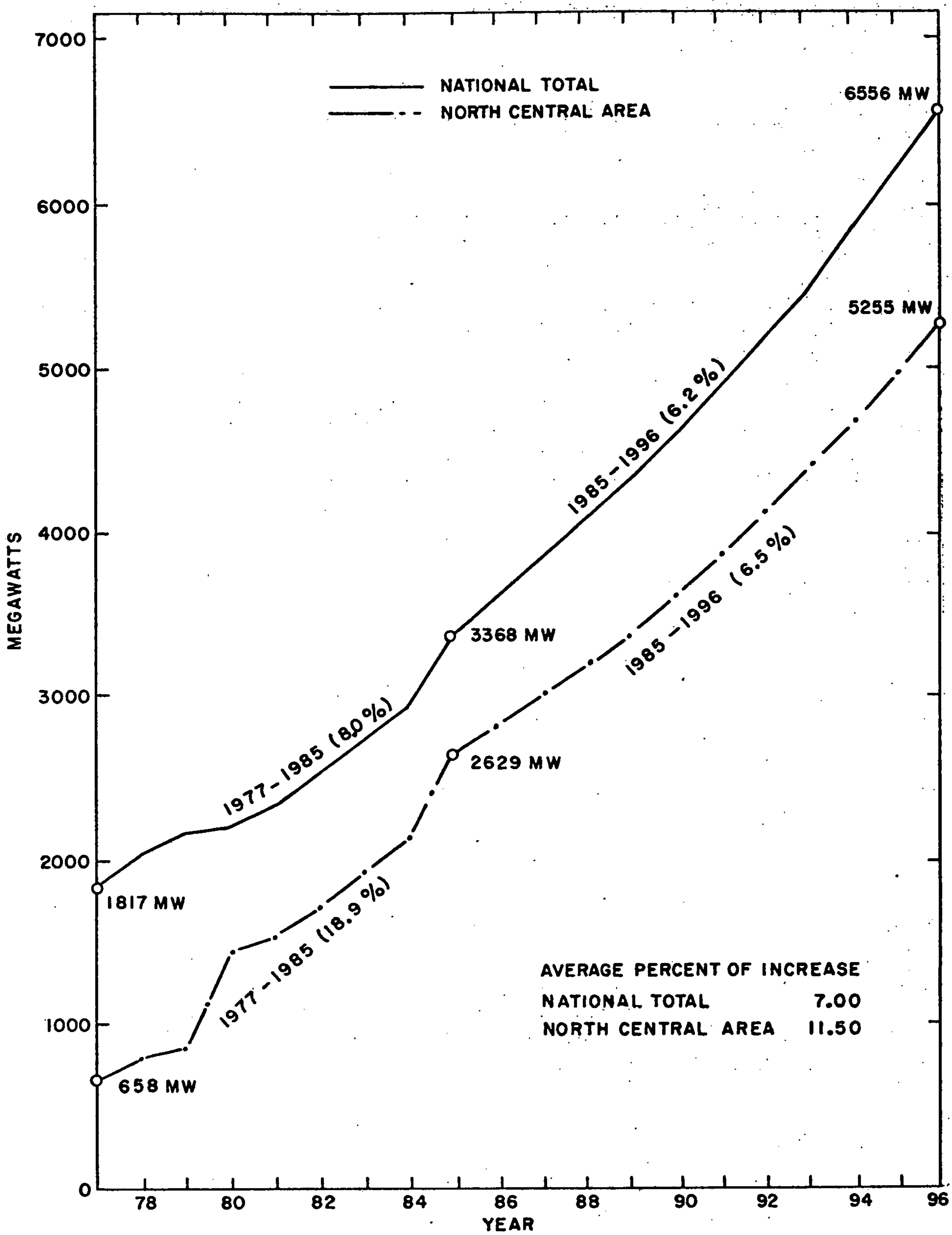
** Estimates by U.S. Hydropower Team based on principles endorsed by Minister of Energy and Mines.

CHART 2
(Projections of the Electrical Demands)
(Southwest, Southeast (Cusco), Isolated Loads)



Source: Ministry of Energy and Mines

CHART 1
(Projections of the Electrical Demand)
(National Total - North Central Area)



Source: Ministry of Energy and Mines

Table 8 HYDROPOWER POTENTIAL 1/ concluded

RIVER BASIN	TOTAL LENGTH OF RIVERS & TRIB.	MEAN ANNUAL RUNOFF		POTENTIAL HYDROPOWER MEGAWATTS	
		DEPTH	VOLUME		
	Km	MM	MILLIONS M^3	TOTAL	IN PERU
Atlantic continued					
Amazonas	2988	1422	7913	5795	5795
Napo	2918	1689	7570	3142	3142
Putumayo	2130	1428	5730	662	343
Yavari	1875	1799	10645	7077	6305
Purus	825	963	16275	269	269
Madre De Dios	1005	1813	6817	5429	5429
Inambari	570	1621	32995	1085	1085
Tambopata	470	893	13136	1187	1187
Acre	170	948	3062	36	18
Las Piedras	520	966	15021	609	609
Yurua	565	967	9179	264	254
Subtotals			362,526		163,617
TITICACA					
Suches	168	222	323	33	24
Huancane	437	242	861	64	64
Ramis	1426	183	2643	228	228
Coata	557	265	1261	152	152
Illpa	181	206	240	14	14
Ilave	767	134	1069	61	61
Maure	227	64	108	12	12
Zapatilla	80	263	125	2	2
Subtotals			6,630		557
SUMMARY OF TOTALS					
PACIFIC			29,949		29,954
ATLANTIC			362,526		163,617
TITICACA			6,630		557
TOTALS			399,105		194,128

1/ Preliminary data from studies made by Lahmeyer International for Republic of Germany in cooperation with the Government of Peru, and is the theoretical potential.

Table 8 HYDROPOWER POTENTIAL 1/ continued

RIVER BASIN	TOTAL LENGTH OF RIVERS & TRIB.	MEAN ANNUAL RUNOFF DEPTH	VOLUME	POTENTIAL HYDROPOWER MEGAWATTS	
	Km	MM	MILLIONS M^3	TOTAL	IN PERU
Pacific cont.					
Tambo	919	91	1155	1423	1423
Osmore O Moquegua	321	37	133	170	170
Locumba	384	25	133	384	384
Sama	278	16	77	83	83
Caplina	126	37	60	54	54
Subtotal			29,949		29,954
ATLANTIC					
Alto Maranon	1932	815	23227	8572	8572
Chrisnejas	700	251	1170	605	605
Llaucano	303	525	1497	759	759
Chamaya	197	476	1609	727	727
Huancabamba	301	261	900	310	310
Chotano	183	577	977	333	333
Chinchipe	375	569	4071	814	499
Tabaconas	225	716	2715	889	889
Cenepa	434	441	3246	313	313
Santiago	2091	1699	5607	5509	3277
Maranon Medio	1854	553	13396	6503	6503
Morona	830	1571	25246	2585	1753
Pastaza	2692	1457	5972	10955	1651
Tigre	1914	1838	6271	4817	4817
Bajo Maranon	1867	1164	5207	2731	2731
Utcubamba	334	512	3844	1232	1232
Chiriaco	247	458	1889	832	832
Nieva	355	247	1070	258	258
Huallaga (Upper)	4324	744	5590	21834	21834
Huallaga (Lower)	1158	715	12465	823	823
Urubamba	682	392	2851	5795	5795
Vilcanota	3536	677	3523	10591	10591
Apurimac (Upper)	1522	337	4562	1884	1884
Santo Tomas	372	600	1843	593	593
Punanqui	79	605	480	99	99
Vilcabamba	227	634	1633	568	568
Pachachaca	427	596	3342	1347	1347
Apurimac (Lower)	1057	645	9905	12644	12644
Pampas	1446	324	7692	4403	4403
Mantaro (Upper)	917	308	2830	683	683
Mantaro (Middle)	1207	336	6243	4469	4469
Mantaro (Lower)	555	572	3903	5026	5026
Pachitea	1355	1428	3850	6146	6146
Aquaytia	652	1244	14356	1085	1085
Ene	451	1099	8326	2015	2015
Tambo	293	1121	5797	2127	2127
Ucayali	4667	1145	12815	14203	14203
Perene	1146	694	14263	6785	6785

Table 8 HYDROPOWER POTENTIAL 1/

RIVER BASIN	TOTAL LENGTH OF RIVERS & TRIB. Km	MEAN ANNUAL RUNOFF DEPTH MM	MEAN ANNUAL RUNOFF VOLUME MILLIONS M^3	POTENTIAL HYDROPOWER MEGAWATTS TOTAL	POTENTIAL HYDROPOWER MEGAWATTS IN PERU
PACIFIC					
Zarumilla	129	214	175	17	10
Tumbes	236	198	540	284	186
Chira	1033	193	2232	722	596
Piura	719	87	911	209	209
Cascajal	288	22	91	21	21
Olmos	91	23	22	22	22
Motupe	237	92	179	61	61
La Leche	150	199	314	107	107
Chancay-Lambayeque	395	207	1015	531	531
Zana	169	93	193	138	138
Chaman	99	63	79	19	19
Jaquetepeque	408	161	685	628	628
Chicama	451	201	895	443	443
Moche	304	124	268	278	278
Viru	225	43	85	153	153
Chao	161	75	108	113	113
Santa	1140	378	4717	4940	4940
Lacramarca	71	2	1	9	9
Nepena	266	21	40	89	89
Casma	305	47	144	211	211
Culebras	105	2	1	16	16
Huarmey	187	64	150	174	174
Fortaleza	280	20	47	112	112
Pativilca	514	307	1507	1675	1675
Supe	114	42	45	75	75
Huara	360	225	1009	1090	1090
Chancay-Huaral	243	189	639	610	610
Chillon	211	155	366	345	345
Rimac	298	317	993	871	871
Lurin	166	88	141	176	176
Chilca	96	56	45	29	29
Mala	236	218	550	560	560
Omas	101	70	122	82	82
Canete	563	303	1812	2002	2002
Topara	60	78	38	24	24
San Juan	310	120	640	798	798
Pisco	349	136	551	911	911
Ica	339	68	501	446	446
Grande	1129	46	484	364	364
Acari	339	114	465	676	676
Yauca	357	80	367	306	306
Chalo O Indio Muerto	161	42	54	40	40
Chaparra	141	60	83	67	67
Atico	151	34	48	32	32
Caraveli	196	49	98	75	75
Ocona	1430	138	2195	3223	3223
Majes-Camana	1039	110	1885	3155	3155
Quilca O Chili	881	65	861	1142	1142

A summary of the theoretical potential hydropower by river basins in the Pacific, Atlantic, and Lake Titicaca areas of Peru is shown in Table 8. That table also shows the length of the rivers in kilometers, the depth of runoff in mm, the annual runoff in millions of M^3 as well as the estimated power in MW.

Projected Load Growth

The Minister of Energy and Mines of Peru has estimated the National load growth at 7 percent. In contrast, the load growth in the Central-North area of Peru, which includes Lima, is forecast to grow at a rate of 11.5 percent from 1977 to 1996. Two charts showing the projected national growth of capacity demands, and the projected growth for the principal areas of Peru are included in Charts 1 and 2. These charts cover the period of 1977 through 1996, and were prepared in October, 1977.

The total electrical demands and the demands for hydropower of the principal electric systems are shown in Table 9 for years 1977, 1985, 1989, 1996, and 2000. The total demand estimates were made by the Minister of Energy and Mines as shown in the December, 1977 "Plan De Electrificacion Nacional". The estimates for hydropower and for extension of the total demands to the year 2000 were made by the U.S. Hydropower Team based on the principles endorsed by the Minister of Energy and Mines. The key principle relates to meeting future electrical demands mainly by hydropower, thus decreasing the use of oil and gas for electrical energy.

Plans for Additions to Principal Hydropower Plants

The Republic of Peru has scheduled the development of needed electrical facilities to 1990. These projections are described and evaluated in the report by the Minister of Energy and Mines titled "Plan De Electrificacion Nacional" dated December 1977. The plans for additions to the principal

Hydropower Potential

Hydropower depends on head and water supply. In Peru both of these variables range between wide limits. Elevations range from sea level to over 6760 M (22,200 FT) above sea level at Mount Huascaran. The drainage area of Peru totals 1,285,220 square kilometers (496,200 Mi^2) of which about 11 percent drains to the Pacific and the remainder to the Atlantic and to Lake Titicaca. The Pacific or western portion of Peru has runoff in depth ranging from zero along portions of the coast to about 400 mm (16 in) annually in the Santa River basin in northern Peru. In contrast, the eastern or Atlantic portion of Peru has runoff ranging in depth from about 400 mm to 2000 mm (16 to 79 in). Hydropower development also depends on storage regulation and on the criteria used for formulating plans for development which is largely a function of engineering and economics.

During the late 1960's the government of Peru with the assistance of the Federal Republic of Germany undertook an assessment of the future demands for electric energy and the hydroelectric potential of Peruvian water supplies. The assessment and projections were carried forward to year 1985. This previous assessment is now being updated. The German consulting firm of Lahmeyer International is providing technical assistance and working with Peruvian personnel on the elaboration of an optimal expansion program for the electrical supply system of the country. The hydropower estimate has taken into account drainage areas, elevations, lengths of rivers and streams, rainfall, and runoff covering a total area of 698,391 KM^2 (269,650 Mi^2). Each stream has been broken into increments for computing potential hydro capacity. The computations have been computer-programmed and correlated with available streamflow, rainfall, runoff, and elevation records.

Table 7

PRESENT PRINCIPAL HYDROPOWER PLANTS

PERU *

NORTH REGION (Chimbote-Trujillo, etc.)

	Capacity-Megawatts
Canon Del Pato	100
Cahua	40
Subtotal	140

CENTRAL REGION (Lima-Pisco, etc.)

Chaprin	5.4
Yaupi	108
Malpaso	54.4
La Oroya	9
Carpapata	12.2
Pachachaca	12
Huinco	260
Matucana	120
Callahuanca	67.5
Moyopampa	63
Huampani	31.4
Ingenio	
Sicaya Huarisca	
Mantaro	342
Subtotal	1,084.9

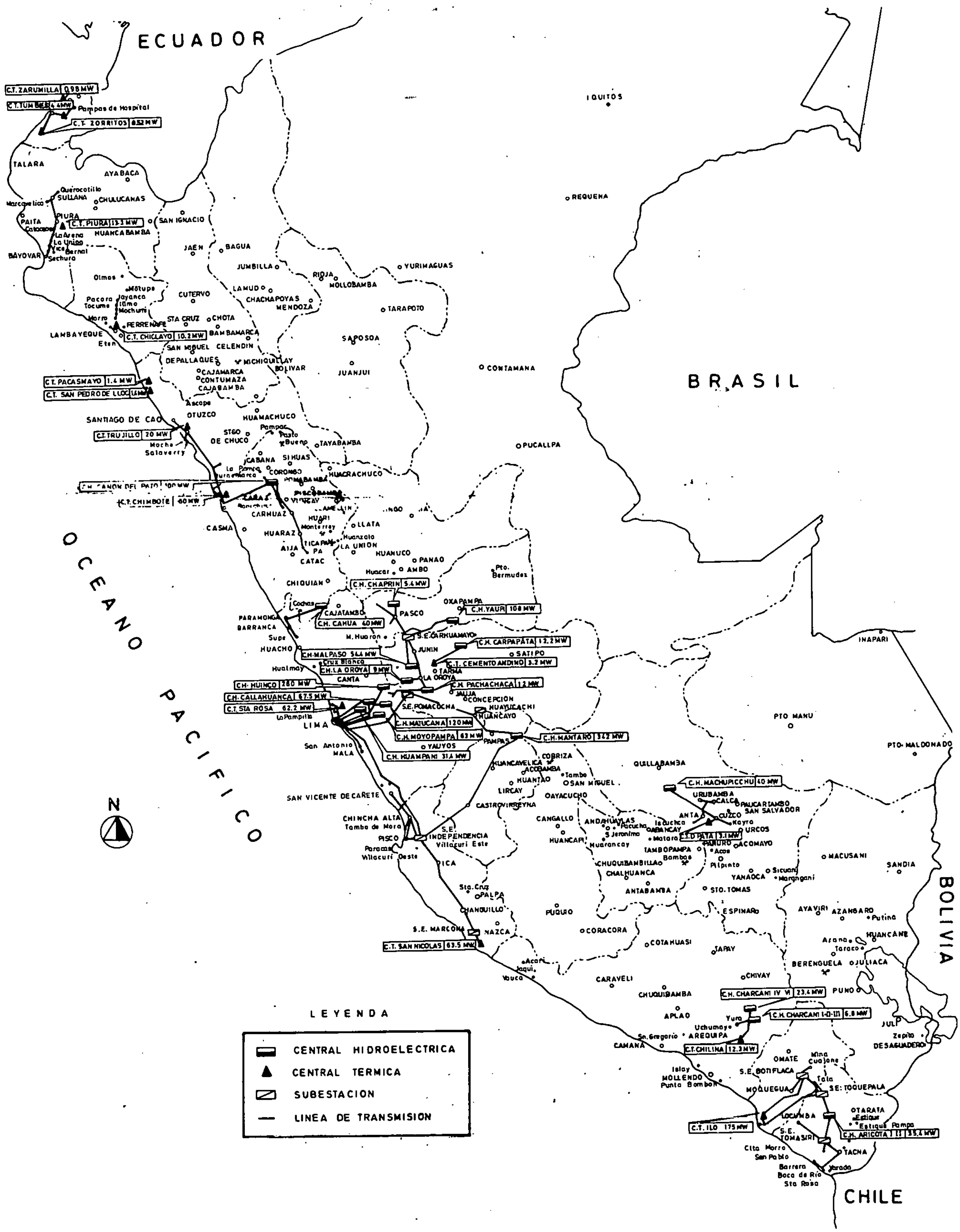
SOUTH REGION (Arequipa-Cuzco-Moquegua, etc.)

Machupicchu	40
Charcani IV-VI	23.4
Charcani I-II-III	6.8
Aricota I-II	35.4
Subtotal	105.6

SUMMARY

NORTH REGION	140
CENTRAL REGION	1,084.9
SOUTH REGION	105.6
TOTAL	1,330.5

*From "Plan De Electrificacion Nacional", Ministerio De Energia Y Mines. December 1977.


ECUADOR
BRASIL
BOLIVIA
CHILE
OCEANO PACIFICO
N
IQUITOS
REQUENA
YURIMAGUAS
TARAPOTO
CONTAMANA
PUCALLPA
INAPARI
PTO MANU
PTO· MALDONADO
C.T. ZARUMILLA 0.98 MW
C.T. ZORRITOS 0.52 MW
Pampas de Hospital
TALARA
AYABACA
SULLANA
CHULUCANAS
PAITA
PIURA
C.T. PIURA 13.3 MW
HUANCABAMBA
SAN IGNACIO
JAEN
BAGUA
BAYOVAR
Sechura
Olmos
CUTERVO
CHOTA
STA CRUZ
LAMBAYEQUE
C.T. CHICLAYO 10.2 MW
BAMBAMARCA
CELENDIN
JUMBILLA
RIOJA
MOLLOBAMBA
LAMUD
CHACHAPOYAS
MENDOZA
SAPOSOA
JUANJUI
BOLIVAR
CAJAMARCA
CONTUMAZA
CAJABAMBA
C.T. PACASMAYO 1.4 MW
SANTIAGO DE CAO
OTUZCO
HUAMACHUCO
C.T. TRUJILLO 20 MW
Salaverry
TAYABAMBA
HUACRACHUCO
CABANA
SIHUAS
C.T. CHIMBOTE 60 MW
CARHUAZ
HUARI
CASMA
HUARAZ
LLATA
AIJA
CATAC
LA UNION
HUANUCO
PANAO
AMBO
Pto. Bermudez
CHIQUIAN
C.H. CHAPRIN 5.4 MW
CAJATAMBO
C.H. CAHUA 40 MW
PASCO
OXAPAMPA
C.H. YAUPI 108 MW
PARAMONGA
BARRANCA
Supe
HUACHO
S.E. CARHUAMAYO
C.H. CARPAPATA 12.2 MW
JUNIN
SATIPO
C.T. CEMENTO ANDINO 3.2 MW
C.H. MALPASO 54.4 MW
C.H. LA OROYA 9 MW
TARMA
LA OROYA
CANTA
C.H. PACHACHACA 12 MW
C.H. HUINCO 280 MW
C.H. CALLAHUANCA 67.5 MW
C.T. STA ROSA 62.2 MW
JAUJA
CONCEPCION
S.E. POMACOCHA
HUAYUCACHI
HUANCAYO
LIMA
C.H. MATUCANA 120 MW
C.H. MOYOPAMPA 63 MW
C.H. MANTARO 342 MW
PAMPAS
YAUYOS
C.H. HUAMPANI 31.4 MW
San Antonio
MALA
HUANCAVELICA
COBRIZA
LIRCAY
AYACUCHO
SAN VICENTE DE CAÑETE
CASTROVIRREYNA
CHINCHA ALTA
Tambo de Mora
PISCO
S.E. INDEPENDENCIA
ICA
CANGALLO
ANDAHUAYLAS
ABANCAY
HUANCAPI
QUILLABAMBA
C.H. MACHUPICCHU 40 MW
URUBAMBA
CALCA
PAUCARTAMBO
SAN SALVADOR
ANTA
CUZCO
URCOS
ACOMAYO
TAMBOPAMPA
CHUQUIBAMBILLA
CHALHUANCA
ANTABAMBA
YANAOCA
STO. TOMAS
ESPINAR
MACUSANI
SANDIA
PALPA
S.E. MARCONA
NAZCA
C.T. SAN NICOLAS 63.5 MW
PUQUIO
CORACORA
COTAHUASI
AYAVIRI
AZANGARO
HUANCANE
JULIACA
PUNO
CARAVELI
CHUQUIBAMBA
APLAO
CHIVAY
C.H. CHARCANI IV VI 23.4 MW
AREQUIPA
CAMANA
C.T. CHILINA 12.3 MW
DESAGUADERO
MOLLENDO
OMATE
S.E. BOTIFLACA
MOQUEGUA
S.E. TOQUEPALA
C.T. ILO 175 MW
LOCUMBA
TARATA
TACNA
LEYENDA
CENTRAL HIDROELECTRICA
CENTRAL TERMICA
SUBESTACION
LINEA DE TRANSMISION

HYDROPOWER

Peru has many large streams which are sources of hydropower to meet a large portion of the electrical demands of the country. The Peruvian Government has recognized this resource and has established a policy promoting its development for multiple purposes, particularly for irrigation, municipal, and industrial water supplies.

Hydroelectric development is concentrated in the coastal zone to service the large metropolitan and industrial demand located in that zone. A substantial portion of the hydropower is located in vicinity of Lima which is growing rapidly. Its present metropolitan population of some 4,500,000 is expected to be 10,000,000 to 15,000,000 at the turn of the century. Thus the urgent need for additional electrical service is apparent.

Present Electrical Facilities

In 1975, the hydroelectric power generation was 5470 gigawatt hours (GWH), or 73.1 percent of the total electrical generation of 7486.2 GWH. Unofficial figures for the year 1977 show that the installed hydroelectric capacity was 1406.5 MW with a corresponding energy production of 5825.3 GWH. The 1977 values for hydroelectric installed capacity and energy are about 55.3 and 71.4 percent of the corresponding total values for the country. Much of the thermal power is in diesel plants.

The Minister of Energy and Mines of Peru has prepared a map dated October, 1977, showing the principal electrical facilities in existence which is included in this report on page 31. The present principal hydropower plants in Peru, as shown on the map are summarized in Table 7.

million M^3 (18,694,000 AF), or about 95 percent of the total. Urban use accounts for about 947 million M^3 (768,000 AF), or about 4 percent of the total, leaving 294 million M^3 (238,000 AF), or 1.2 percent of the total which is used for mining and livestock.

The water used is divided among the three general regions as follows:

Region	Water used annually - Million m^3				
	Irrigation	Urban	Livestock	Mines	Total
Costa	15878.78	736.04	35.86	168.12	16818.80
Sierra	6187.44	176.28	49.91	38.52	6452.15
Selva	992.77	34.59	1.88	0	1029.24
Total	23058.99	946.91	87.65	206.64	24300.19
Percent	94.89	3.90	0.36	0.85	100.00

Pacific	Number
Santa River Basin	40
Huarmey River Basin	20
Canete River Basin	20
Chancay-Huaral River Basin	19
	99
Atlantic	
Mantaro River Basin	32
Perene River Basin	31
	63
Titicaca	
Maure River Basin	1
Costa River Basin	2
Ilpa River Basin	1
	4

Transmountain Diversions

Development of available surface water supplies in the Pacific drainage is near a maximum without additional storage regulation of the seasonal high flows. The lack of rainfall on the Pacific slopes and seasonal deficiencies in flows of the rivers that cross the coastal desert have led to the construction of dams which only partly regulate flows so that irrigation as well as some municipal and industrial requirements are not fully satisfied. This situation results in economic losses as well as uncertainties in agricultural production and in future water supplies for rapidly growing coastal cities.

The available supplies in the Pacific area are presently supplemented by transmountain diversions of water from the Maranon and Montaro River systems of the Atlantic watershed. Other transmountain diversions of water from the Atlantic are needed to sustain growth in the coastal region.

Present Water Uses

The present annual water use in Peru totals about 24,300 million M^3 (19,700,000 AF). Of this amount irrigated agriculture accounts for 23,059

Table 6

GENERAL RESULTS OF THE NATIONAL SURVEY OF LAKES

WATERSHED	NUMBER OF SURVEYED LAKES	NUMBER OF UNSURVEYED LAKES	TOTAL LAKES	LAKES DEVELOPED		LAKES UNDER STUDY		LAKES UNDETERMINED
				NUMBER	CAPACITY*	NUMBER	CAPACITY*	
PACIFIC	2,245	1,651	3,896	105	1,378.58	204	616.42	33
CLOSED BASINS	8	15	23	3	41.00	1	185.00	–
ATLANTIC	4,138	3,303	7,441	76	1,604.37	133	3,006.42	7
TITICACA	464	377	841	2	4.12	4	145.00	2
TOTAL	6,855	5,346	12,201	186	3,028.07	342	3,952.84	42

* Usable Capacity in Millions of M^3.

as dams, tunnels, canals, and pumping plants. A general survey made by the Government of Peru identified a total of 12,201 natural lakes of which about 6,855 have been surveyed. The remaining 5,346 lakes have only been counted.

Table 6 shows that 186 lakes have been developed with a total usable capacity of 3,028 million M^3 (2,455,000 AF); 342 lakes with a total usable capacity of 3,952.84 million M^3 (3,205,000 AF) are being studied; and 42 lakes are of undetermined status.

The general survey shows that the largest capacity for storage regulation in natural lakes is in the Locumba River watershed (906.6 million M^3), followed by the Camana River watershed (95 million M^3), and the Rimac River (83.87 million M^3), all in the Pacific drainage. In the Atlantic watershed the river basins with the largest storage capacity are the Mantaro Basin (1,329.82 million M^3) and the Pampas Basin (224.58 million M^3).

The general survey also identifies river basins with the largest number of lakes under present development as follows:

Pacific Watershed	Number
Huarmey River Basin	19
Rimac River Basin	15
Chancay-Huaral Rivers Basin	12
	46
Atlantic	
Mantaro River Basin	29
Perene River Basin	3
	32
Titicaca	
Ramis River Basin	1
Maure River Basin	1
	2

River basins with the largest number of lakes under investigation are identified by the survey as follows:

July through September. The coastal stream with the largest annual discharge is the Rio Santa which enters the Pacific at Chimbote. The second largest in point of mean annual discharge is the Rio Tumbes in the extreme north of Peru.

Headwater tributaries of the Amazon are fed by snowmelt from Andean snow fields as well as by runoff from conventional summer storms on the higher mountain slopes. On the eastern slopes of the Andes rainfall is in places extremely heavy and occasionally torrential, causing extensive flooding in the eastern lowlands along the Maranon, Huallaga, and Ucayali Rivers and their larger tributaries.

Water Quality

Relatively few chemical analyses have been made of the waters of Peru, and most of these concern the coastal desert. Here the water is generally of acceptable quality for most uses, but in places it is mineralized beyond permissable standards. High boron and florides are common in surface and groundwater derived from terrains of volcanic activity as in the Departments of Arequipa, Moquegua and Tacna. Also, in some places, toxic elements such as arsenic, lead, and zinc are present, particularly where water has circulated through or near mineralized rocks. Few data are available on the chemical quality of groundwater in the Andean region and the eastern lowlands. The chemical quality of the water, however, appears to be generally acceptable for most uses.

Storage*

Few storage reservoirs have been constructed in Peru. There are, however, a large number of natural lakes in the highlands that provide storage capacity for stream regulation. A number of these lakes have been converted to storage reservoirs for hydropower, irrigation, urban, industrial and mining uses by construction of appropriate structures such

* Source of Natural Lake Data - "Inventorio De Lagunas Y Represmientos-ONERN.

TABLE 5. DISCHARGE OF SELECTED RIVERS IN PERU 1/

River and stations	Basin area km^2	Mean monthly discharge, m^3/s Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year	Number of years of record
Pacific Slope															
Tumbes, Pta. Tumbes	1.940	140.5	217.1	314.3	318.4	171.1	85.9	45.7	29.6	42.1	41.1	44.2	43.0	124.6	13
Chira, Pta. Sullana	10.100	79.2	205.1	288.4	293.2	137.1	80.6	55.9	39.6	32.5	31.9	27.9	35.3	109.4	21
Piura, Pta. Piura	12.540	3.6	59.9	108.2	89.7	30.0	12.5	6.1	3.4	1.8	1.1	0.7	0.5	25.4	47
La Leche, Puchaca	1.740	5.4	10.0	17.4	14.5	7.6	4.9	3.1	2.3	3.6	4.0	2.9	1.0	6.6	44
Chancay (Lamb.). Carhuaquero	5.130	24.7	44.0	66.4	69.5	38.2	20.0	10.8	7.3	8.4	15.3	16.3	18.0	28.2	50
Zana, El Baran	2.000	5.5	10.2	15.3	17.2	11.2	0.8	4.1	2.8	2.7	3.8	3.7	3.7	8.3	41
Jequetepeque, Ventanillas	4.200	24.8	51.5	93.4	81.0	32.0	13.2	7.1	4.8	3.9	7.9	10.1	13.0	28.5	38
Chicama, Salinar	4.770	33.1	66.9	102.5	78.2	29.6	12.4	7.6	5.5	5.9	6.4	5.7	8.7	30.2	49
Moche, Quirihua	2.130	9.9	16.8	34.2	29.6	10.1	2.5	1.2	0.7	0.8	1.6	2.3	3.9	9.6	47
Viru, Huacapongo	1.950	4.3	10.4	14.8	10.0	4.0	0.7	0.3	0.1	0.1	0.5	1.0	1.3	3.9	23
Santa, Pta. Carretera	11.700	203.5	270.1	350.7	274.1	146.1	91.5	60.3	53.9	53.8	67.3	85.3	125.0	149.1	23
Nepena, San Jacinto	1.810	2.1	6.1	9.0	5.1	1.9	1.0	0.8	0.6	0.4	0.4	0.4	0.7	2.4	23
Casma, Pta. Carretera	2.900	5.6	18.4	23.2	14.6	3.7	1.0	0.5	0.3	0.2	0.3	0.8	1.5	5.7	27
Huarmay, Pta. Carretera	2.100	2.7	9.7	16.5	12.2	2.2	0.2	0.1	0.1	0.0	0.0	0.7	0.6	1.7	19
Pativilca, Alpas	4.700	63.5	102.3	123.4	77.5	36.4	20.4	15.5	14.1	15.2	22.3	28.0	33.0	46.0	24
Huaura, Casa Blanca	5.470	40.6	57.8	65.1	43.1	22.9	15.6	12.7	10.9	10.5	14.0	17.9	24.8	27.9	31
Chancay (Huar), Santo Domingo	3.030	23.3	36.1	40.1	24.6	10.4	5.3	4.6	4.0	4.3	5.1	6.4	9.5	14.6	35
Chillon, Pta. Magdalena	2.020	13.3	24.3	31.1	16.8	5.7	3.3	2.5	2.0	1.9	2.0	2.4	5.2	9.3	37
Rimac, Chosica	3.540	39.5	64.6	78.1	41.4	21.8	14.3	12.0	11.8	12.8	13.4	15.8	22.5	29.0	50
Lurin, Manchay	2.500	6.3	15.0	9.3	8.2	2.5	0.8	0.2	0.0	0.0	0.0	0.5	0.6	3.7	20
Mala, La Capilla	2.130	37.1	50.8	62.1	20.5	7.2	2.8	2.1	1.8	1.6	2.8	6.9	13.8	18.0	23
Caneta, Toma Imperial	8.750	94.8	144.0	160.9	87.1	38.2	20.8	14.7	12.0	11.2	13.1	24.4	42.2	55.1	48
San Juan, Canta	3.910	25.7	52.5	67.8	21.5	4.3	1.3	0.7	0.3	1.4	2.1	2.1	6.6	15.7	33
Pisco, Latrayos	4.440	52.2	86.7	93.3	35.5	10.5	4.3	2.4	2.1	1.9	3.5	7.8	16.2	26.5	46
Ica, Huarmani	7.300	17.4	39.7	43.6	14.2	2.2	0.7	0.3	0.2	0.3	0.8	0.8	5.2	10.6	47
Grande, Pta. Carretera	12.594	30.5	75.8	68.1	27.3	5.2	2.9	0.4	0.3	0.3	0.0	0.0	0.7	17.5	27
Acan, T. Bella Union	4.131	20.8	50.6	48.5	16.7	6.7	3.1	2.0	0.9	8.7	0.7	1.3	3.2	12.9	12
Yauca, Pta. Yaqui	4.541	13.9	35.5	33.4	10.7	3.5	1.5	0.8	0.9	0.8	0.8	1.0	2.3	8.7	14
Camana o Majes, Huariaua	17.300	170.5	260.2	267.5	109.0	64.5	41.1	35.9	30.4	27.7	27.1	28.4	51.1	93.6	15
Chili, Charcani	12,843	24.6	38.9	34.3	15.4	6.6	5.0	5.0	4.6	4.4	4.4	4.3	7.2	12.9	30
Tambo, Chucara	12,910	44.5	100.4	38.1	35.0	24.3	20.7	18.7	16.5	12.5	12.5	9.9	18.7	33.2	19
Moquequa, Tumilaca	3.441	2.5	4.7	5.0	1.7	1.4	1.1	1.1	1.0	1.1	1.1	1.2	1.2	1.9	11
Caolina, Calientes	2.246	1.5	2.9	2.1	1.0	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.2	23
Uchusuma, Piedra Blanca	-	0.4	1.0	0.5	0.3	0.4	0.4	0.4	0.4	0.3	0.4	0.2	0.3	0.4	20
Titicaca Basin															
Ramis, Pta. Carretera	14.840	150.8	217.0	208.1	112.5	55.8	32.3	21.8	16.2	14.0	18.0	21.3	68.1	77.8	7
Amazon Basin															
Huancabamba	-	17.2	23.2	24.0	24.1	20.4	18.2	14.8	15.3	12.5	14.8	16.3	14.4	17.9	-
Mantaro, La Mejorada	17.500	216.7	348.0	389.3	239.9	158.4	124.3	117.1	105.7	105.3	107.9	122.9	173.8	184.0	16
Chamaya, La Savila	2.000	52.0	73.4	105.4	105.7	81.4	59.7	49.4	41.2	43.4	53.9	49.2	37.0	63.7	11

1/ Based on data from ECLA, 1968.

Table 4. WATER RESOURCES 1/ Concluded

RIVER BASIN	AREA KM²	MEAN ELEV. M	MEAN AN. PRECIP MM	RUNOFF COF.	MEAN ANNUAL RUNOFF DEPTH MM	MEAN ANNUAL RUNOFF MILLION M³
Atlantic continued						
Amazonas	5565	113	2734	0.52	1422	7913
Napo	4482	228	2769	0.61	1689	7570
Putumayo	4013	160	2747	0.52	1428	5730
Yavari	5917	370	2811	0.64	1799	10645
Purus	16900	414	1888	0.51	963	16275
Madre De Dios	3760	1297	3358	0.54	1813	6817
Inambari	20355	2261	3118	0.52	1621	32995
Tambopata	14710	990	1624	0.55	893	13136
Acre	3230	454	1859	0.51	948	3062
Los Piedras	15550	396	1895	0.51	966	15021
Yurua	9492	329	1935	0.50	967	9179
Subtotal	1024450*					362,526
TITICACA						
Suches	1453	4656	601	0.37	222	323
Huancane	3557	4259	692	0.35	242	861
Ramis	14444	4307	676	0.27	183	2643
Coata	4757	4338	854	0.31	265	1261
Illpa	1165	4133	737	0.28	206	240
Ilave	7977	4333	462	0.29	134	1069
Maure	1687	4542	403	0.16	64	108
Zapatilla	474	4011	598	0.44	263	125
Subtotal	35,514					6,630
SUMMARY OF TOTALS						
PACIFIC	229,095					29,950
ATLANTIC	1,024,450*					362,530
TITICACA	35,514					6,630
TOTAL INCLUDED IN STUDIES	1,289,059					399,110

1/ Preliminary data from studies made by Lahmeyer International for Federal Republic of Germany in cooperation with the Government of Peru.

* Corrected subtotal as some discrepancies were noted in areas for each station of Atlantic watershed

Table 4. WATER RESOURCES Continued

RIVER BASIN	AREA KM²	MEAN ELEV. M	MEAN AN. PRECIP. MM	RUNOFF COF.	MEAN ANNUAL RUNOFF DEPTH MM	MEAN ANNUAL RUNOFF MILLION M³
Pacific cont.						
Tambo	12697	3472	351	0.26	91	1155
Osmore O Moquesua	3595	1971	108	0.34	37	133
Locumba	5316	2599	176	0.14	25	133
Sama	4809	2260	107	0.15	16	77
Caplina	1629	3095	167	0.22	37	60
Subtotal	229,095					29,949
ATLANTIC						
Alto Maranon	28500	3009	815	1.00	815	23227
Chrisnejas	4660	3150	762	0.33	251	1170
Llaucano	2852	2572	1030	0.51	525	1497
Chamaya	3380	1682	1035	0.46	476	1609
Huancabamba	3448	2122	688	0.38	261	900
Chotoand	1694	2298	1068	0.54	577	977
Chinchipe	7155	1434	1074	0.53	569	4071
Tabaconas	3792	1941	1234	0.58	716	2715
Cenepa	7360	732	939	0.47	441	3246
Santiago	3300	692	2655	0.64	1699	5607
Maranon Medio	24225	368	1177	0.47	553	13396
Morona	16070	526	2534	0.62	1571	25246
Pastaza	4099	1077	2389	0.61	1457	5972
Tigre	3412	386	2964	0.62	1838	6271
Bajo Maranon	4473	176	2376	0.49	1164	5207
Utcubamba	7507	1903	840	0.61	512	3844
Chiriaco	4125	1755	803	0.57	458	1889
Nieva	4330	711	603	0.41	247	1070
Huallaga Sup	7513	1515	1403	0.53	744	5590
Huallaga Inf.	17433	255	1430	0.50	715	12465
Urubamba	7272	4366	753	0.52	392	2851
Vilcanota	5204	1577	1253	0.54	677	3523
Apurimac Sup	13538	4237	732	0.46	337	4562
Santo Thomas	3072	4196	909	0.66	600	1843
Punanqui	793	4103	903	0.67	605	480
Vilcabamba	2575	4356	932	0.68	634	1633
Pachachaca	5608	4157	993	0.60	596	3342
Apurimac Inf.	15356	2960	948	0.68	645	9905
Pampas	23742	3821	853	0.38	324	7692
Mantaro Sup	9190	4333	810	0.38	308	2830
Mantaro Med	18580	3958	782	0.43	336	6243
Mantaro Inf.	6823	3078	763	0.75	572	3903
Pachitea	2696	857	2303	0.62	1428	3850
Aquaytia	11540	600	2392	0.52	1244	14356
Ene	7576	945	1691	0.65	1099	8326
Tambo	5171	700	1780	0.63	1121	5797
Ucayali	11192	289	2081	0.55	1145	12815
Perene	20552	2229	1176	0.59	694	14263

Table 4. WATER RESOURCES 1/

RIVER BASIN	AREA KM^2	MEAN ELEV. M	MEAN AN. PRECIP. MM	RUNOFF COF.	MEAN ANNUAL RUNOFF DEPTH MM	MILLION M^3
PACIFIC						
Zarumilla	817	279	369	0.58	214	175
Tumbes	2729	362	422	0.47	198	540
Chira	11564	960	550	0.35	193	2232
Piura	10475	539	377	0.23	87	911
Cascajal	4147	227	219	0.10	22	91
Olmos	965	730	385	0.06	23	22
Motupe	1951	665	279	0.33	92	179
LaLeche	1578	1255	584	0.34	199	314
Chancay-Lambayeque	4906	1509	669	0.31	207	1015
Zana	2080	1069	514	0.18	93	193
Chaman	1248	671	370	0.17	63	79
Jaquetepeque	4257	2220	731	0.22	161	685
Chicama	4454	1772	558	0.36	201	895
Moche	2161	2221	496	0.25	124	268
Viru	1967	2015	429	0.10	43	85
Chao	1443	1433	324	0.23	75	108
Santa	12478	3410	651	0.58	378	4717
Lacramarca	685	1560	161	0.01	2	1
Nepena	1885	2034	266	0.08	21	40
Casma	3064	2309	315	0.15	47	144
Culebras	671	1615	191	0.01	2	1
Huarmey	2343	2488	353	0.18	64	150
Fortaleza	2342	2434	330	0.06	20	47
Pativilca	4908	3078	480	0.64	307	1507
Supe	1078	2165	302	0.14	42	45
Huara	4483	3061	592	0.38	225	1009
Chancay-Huaral	3382	2665	410	0.46	189	639
Chillon	2364	2478	361	0.43	155	366
Rimac	3134	3157	520	0.61	317	993
Lurin	1600	2456	326	0.27	88	141
Chilca	798	1589	170	0.33	56	45
Mala	2522	2999	427	0.51	218	550
Omas	1741	1702	188	0.37	70	122
Canete	5981	3645	541	0.56	303	1812
Topara	494	1993	216	0.36	78	38
San Juan	5333	2567	353	0.34	120	640
Pisco	4054	3049	468	0.29	136	551
Ica	7366	1756	183	0.37	68	501
Grande	10522	2138	285	0.16	46	484
Acari	4082	3013	438	0.26	114	465
Yauca	4589	2757	380	0.21	80	367
Chalo O Indio Muerto	1284	2072	234	0.18	42	54
Chaparra	1387	2776	332	0.18	60	83
Atico	1425	2239	226	0.15	34	48
Caraveli	2009	2516	286	0.17	49	98
Ocona	15908	3719	768	0.18	138	2195
Majes-Camana	17141	3509	552	0.20	110	1885
Quilca O Chili	13254	3422	343	0.19	65	861

remote areas and lack of strong socioeconomic incentives. Moreover, in the eastern lowlands, particularly, there is an abundance of streamflow which far exceeds present water demands or those projected in the foreseeable future.

It is impractical for the purpose of this report to list the 400 or more stations at which hydrologic data have been obtained. The data have been used, however, in estimating runoff from the numerous river basins on both sides of the Andes in connection with current studies directed at inventorying the country's resources for hydropower development.

Briefly, the method being used in estimating runoff involves the following steps:

1. Creation of a hydrological data bank of streamflow, rainfall, sedimentation, and evaporation.
2. Creation of a mathematical model of each river basin operating on derived hydrologic-morphometric relationships.
3. The historic data was fed into the correlation models for record extension.
4. Curves of elevation vs specific discharge, and elevation vs mean rainfall were developed for use in the mathematical models.
5. Runoff coefficients were developed for each river basin in percent of mean annual rainfall to obtain the depth of rainfall on the watershed that constitutes outflow from the basin.
6. The runoff coefficient multiplied by the mean annual rainfall multiplied by the drainage area gives the mean annual discharge from the basin.

Preliminary results of the studies are shown in Table 4 for some 110 river basins in the Pacific, Atlantic, and Lake Titicaca watersheds.

Table 5 presents the mean monthly and annual discharges of a number of rivers in Peru where detailed data were available. Most of the rivers are on the Pacific slopes where the best and most complete records exist. As shown in the table the high flows of Pacific slope streams commonly occur during the months of February through April with low flows during

Table 3
Mean Annual Rainfall (mm)
In River Basins of Peru *

River Basin	Rainfall	River Basin	Rainfall	River Basin	Rainfall
Zarumilla	369	Pisco	468	Huallaga (Lower)	1430
Tumbes	422	Ica	183	Urubamba	753
Chira	550	Grande	285	Ilcanota	1253
Piura	377	Acari	438	Apurimac (Upper)	732
Cascajal	219	Yauca	380	Santo Tomas	909
Olmos	385	Chala O Indio Muerto	234	Punanqui	903
Motupe	279	Chaparra	332	Vilcabamba	932
La Leche	584	Atico	226	Pachachaca	993
Chancay-Lambayeque	669	Caraveli	286	Apurimac	948
Zana	514	Ocona	768	Pampas	853
Chaman	370	Majes-Camana	552	Mantaro (Upper)	810
Jequetepeque	731	Quilca O Chili	343	Mantaro (Middle)	782
Chicama	558	Tambo	351	Mantaro (Lower)	763
Moche	496	Osmore O Moquequa	108	Panchitea	2303
Viru	429	Locumba	176	Aquaytia	2392
Chao	324	Sama	107	Ene	1691
Santa	651	Caplina	167**	Tambo	1780
Lacramarca	161	Alto Maranon	815***	Ucayali	2081
Nepena	266	Crisnejas	762	Perene	1176
Casma	315	Llaucano	1030	Amazonas	2734
Culebras	191	Chamaya	1035	Napo	2769
Huarmey	353	Huancabamba	688	Putumayo	2747
Fortaleza	330	Chotano	1068	Yavari	2811
Patavilca	480	Chinchipe	1074	Purus	1888
Supe	302	Tabaconas	1234	Madre De Dios	3358
Huara	592	Cenepa	939	Inambari	3118
Chancay-Huaral	410	Santiago	2655	Tambopata	1624
Chillon	361	Maranon Medio	1177	Acre	1859
Rimac	520	Marona	2534	Las Piedras	1895
Lurin	326	Pastaza	2389	Yurua	1935****
Chilca	170	Tigre	2964	Suches	601
Mala	427	Bajo Maranon	2376	Huancane	692
Omas	188	Utcubamba	840	Ramis	676
Canete	541	Chiriaco	803	Coata	854
Topara	216	Nieva	603	Illpa	737
San Juan	353	Huallaga (Upper)	1403	Ilave	462
				Maure	403
				Zapatilla	598

* Data in this table was obtained from preliminary studies made by Lahmeyer International for the Federal Republic of Germany in cooperation with the Government of Peru.
** River Basins listed above Caplina are in Pacific drainage.
*** River Basins listed below Caplina are in Atlantic drainage.
**** River Basins listed below Yurua are in Lake Titicaca drainage.

Table 2. Monthly Mean Rainfall (Inches) for Selected Stations in Peru (Source: Wernstedt, 1972)

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arequipa	1.22	1.02	1.14	0.04	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.20	3.70
Cajamarca	3.74	4.46	5.36	4.25	1.46	0.50	0.19	0.34	1.20	3.42	2.83	3.05	30.80
Cartavio	0.04	0.12	0.04	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.04	0.31
Cerro de Pasco	5.27	6.03	5.05	2.75	1.42	0.63	0.43	0.71	1.95	2.69	4.54	4.96	36.45
Cuzco	6.23	5.05	4.98	1.48	0.35	0.21	0.04	0.32	0.95	1.68	3.17	5.04	29.50
Chacapoyas	3.26	5.33	4.06	3.77	1.58	1.07	0.91	1.09	2.35	3.61	2.89	2.21	32.07
Huancayo	5.36	4.95	4.56	2.00	0.86	0.32	0.20	0.44	1.59	2.81	2.71	3.68	29.48
Imata	5.84	5.80	4.14	1.62	0.60	0.18	0.12	0.06	0.77	0.79	0.92	3.56	24.40
Iquitos	10.24	7.87	10.63	12.36	10.12	6.77	6.97	5.43	8.03	8.62	10.63	9.69	107.36
Juanju	3.62	6.26	5.55	7.99	5.00	2.48	3.15	2.36	4.80	6.61	6.02	4.25	58.11
Lambayeque	0.04	0.28	0.28	0.12	0.04	0.04	0.00	0.00	0.04	0.04	0.04	0.08	0.98
Lima	0.03	0.01	0.03	0.01	0.05	0.13	0.19	0.25	0.18	0.08	0.04	0.02	1.02
Molina (La)	0.04	0.04	0.04	0.04	0.08	0.12	0.12	0.12	0.08	0.04	0.04	0.04	0.79
Piura	0.43	0.67	0.75	0.59	0.04	0.00	0.00	0.04	0.00	0.04	0.04	0.24	2.83
Puno	5.32	5.42	4.31	1.56	0.36	0.24	0.19	0.25	0.93	1.47	1.08	3.45	24.59
San Ramon	9.53	9.61	9.57	8.03	4.72	2.13	2.80	4.57	5.04	6.54	4.88	8.62	76.46
Tacna	0.04	0.03	0.03	0.05	0.15	0.10	0.16	0.30	0.45	0.26	0.03	0.02	1.62
Tingo Maria	16.69	15.88	18.48	13.83	8.53	6.90	6.17	4.41	7.23	13.42	11.37	11.38	134.24
Vitor	0.30	0.33	0.06	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.05	[illegible]8

Table 1. Monthly Mean Temperatures (°F) for Selected Stations in Peru (Source: Wernstedt, 1972)

Station	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Arequipa	57.4	57.7	58.1	56.1	54.9	52.2	52.7	53.8	55.2	56.1	56.1	56.3	55.6
Cajamarca	58.3	57.4	57.6	56.8	57.0	55.8	55.6	57.2	58.1	57.7	58.3	57.7	57.2
Cartavio	73.4	75.4	74.8	71.6	69.8	66.6	64.9	64.4	64.2	64.8	66.2	69.3	68.7
Cerro de Pasco	37.0	36.3	37.9	35.8	34.9	35.8	34.3	36.7	36.0	36.7	38.5	37.6	36.5
Cuzco	53.6	52.5	53.4	52.5	50.4	49.1	47.8	50.4	52.7	54.1	55.2	54.3	51.6
Chacapoyas	60.6	60.3	60.1	59.7	60.4	59.4	58.1	59.2	57.4	60.6	61.7	61.2	60.1
Huancayo	53.8	53.6	53.1	52.9	50.4	49.6	48.7	50.4	53.4	54.3	54.9	54.0	52.2
Imata	40.1	40.5	40.5	38.7	35.4	34.5	34.9	33.8	36.0	36.9	38.5	40.1	37.2
Juanju	81.3	79.9	79.7	79.5	78.8	78.1	78.1	79.3	79.9	80.1	80.4	81.5	79.7
Lambayeque	77.2	79.5	79.2	76.3	73.0	69.6	67.3	66.7	67.5	68.4	70.0	73.0	73.2
Lima	70.5	72.0	72.3	67.6	63.5	60.1	59.4	59.0	59.7	61.2	63.3	66.4	64.4
Molina (La)	73.0	74.5	73.9	70.5	65.5	61.9	60.6	60.4	61.7	63.7	65.8	69.1	66.7
Piura	81.9	84.0	84.0	81.5	77.2	74.3	72.6	73.2	74.3	74.1	75.0	77.5	78.1
Puno	47.3	47.3	48.0	46.4	43.9	42.4	42.8	44.2	45.9	48.6	49.1	48.7	46.0
Tacna	69.1	69.3	66.9	63.7	59.2	56.1	54.9	55.4	57.2	58.8	62.6	65.1	61.7
Tingo Maria	73.0	71.8	72.3	72.1	72.3	71.2	71.6	72.7	72.5	73.0	79.9	74.1	72.5
Vitor	62.8	63.9	64.9	63.9	64.4	64.0	63.5	64.0	64.6	63.4	63.3	63.5	64.0

Temperature Data

Climatological records are available at a number of stations located throughout the country. Mean monthly temperatures at a few selected stations are given in Table 1. Mean monthly temperatures range at these stations from a low of 33.8°F at Imata to a high of 84.0°F at Piura. Average annual temperatures range from a low of 36.5°F at Cerro de Pasco to a high of 79.7°F at Juanju.

Rainfall Records

Table 2 gives the mean rainfall in inches for each month at selected stations throughout the country. Monthly precipitation at the stations varies between 0.00 at Piura and Lambaysque to 18.48 inches at Tingo Maria. Mean annual precipitation varies from 0.31 inches at Cartavio to 134.25 inches at Tingo Maria. Table 3 gives the mean annual rainfall in each of the major river basins east and west of the Andes. Precipitation in river basins draining to the Pacific is generally less than 600 mm (24 in) while rainfall in the basins draining to the Atlantic ranges up to 3358 mm (132 in) in the Madre De Dios river basin.

Streamflow

Hydrologic data have been obtained at more than 400 gaging stations on rivers and streams in Peru. Owing to the paramount importance to irrigated agriculture in the coastal desert, as well as to provision of basic water supply for the urban and industrial water requirements of coastal cities, priority has been given by the Peruvian government to collection of such data for development and management of the rivers of the Pacific slopes. Less attention has been given to collection of streamflow data for rivers of the Andean region and eastern lowlands. The lower priority given to the rivers of these two regions may be attributed to such factors as inaccessibility of gaging sites, technical difficulties in measurement of large rivers in

WATER SUPPLY

Climate

The climate of the coastal area is dominated by a cold ocean current (Humboldt Current) flowing northerly from the Antarctic along the western coast of South America from northern Chile to northern Peru. Due to this current the average air temperature of the Coastal region ranges from 66°F to 73°F during the year. In general the climate is dry and cool; rain almost never falls and little vegetation grows, unless irrigated.

Eastward from the coastal area, climate is determined by a combination of easterly winds prevailing to the east of the Andes and by the mountain chain itself. The warm moist winds blowing across the continent from the Atlantic drop varying amounts of moisture on the slopes and peaks of the Andes. Some of the high valleys and deep gorges between the western and central mountain ranges receive only meager amounts of rain because of the depletion of moist air by the mountain mass, whereas in most areas between the central and eastern mountain ranges the annual rainfall is extremely heavy. The period of heavy rain is during the months September to April. There is a marked dry season in most of the Sierra during the winter months of May through August.

At altitudes above 3350 M (10,990 FT) some snow falls during the winter and at altitudes above 4575 M (15,000 FT) practically all precipitation is in the form of snow.

Rainfall in the high Selva averages 3400 mm (134 in) annually at Tingo Maria where days are hot, but nights are often cool. Temperature averages increase at lower altitudes, although humidity remains high at all elevations In the low Selva, rainfall averages slightly more than 2560 mm (100 in) annually, and there is no dry season. At Iquitos, on the Amazon River, the mean daily temperature is virtually constant throughout the year.

a tunnel through the Andes and drops the water some 4000 M (13,120 FT) to generate power and provide municipal water for the City of Lima and surrounding metropolitan areas.

It was estimated that about 55 percent of the total electrical capacity of 2,542.3 MW in 1977 was hydroelectric and it generated 71 percent of the total electrical energy of 8,155 GWH. As time goes on, it is expected that more of the electricity of the country will be produced by hydropower.

The total electrical needs are expected to increase about 40 to 50 percent by 1985, and to about double from 1985 to 1995. The growth potential of Peru is so great that this estimate could easily be exceeded. In any event, the conditions are favorable for Peru to meet a large portion of its electrical demands by expansion of its hydrosystem, which is in accord with national policy and goals.

Hydropower has been developed through regulated surface water of the Andes dropped through penstocks at high heads to powerplants below. Continuation of such development, along with increasing transmountain diversions from the Amazon drainage to the coastal area, will provide additional opportunities for power generation. As the transmountain diversions become more costly due to increased pumping and longer tunnels, substantial hydropower can be developed in the Amazon basin and transmitted to load centers by large capacity high voltage transmission lines.

and parallels its northward course on the opposite side of the Cordillera Central. Two branches of another major tributary, the Apurimac River, also rise near Cerro de Pasco - one flowing eastward and the other, the Mantaro River, flowing south. The main branch of the Apurimac and the Urubamba cut great gorges between parts of the central range and later combine to form the Ucayali. This river flows northward across the Selva to join the Maranon south of Iquitos to form the Amazon River.

General Overview - Hydropower

The abundance of water east of the Continental Divide, combined with the large potential head east and west of the Divide provides opportunity for increasing the hydropower generation by more than 40 times the present capacity. This potential can be achieved by systematic river basin planning to provide for the best combination of uses of the water supplies to meet needs of irrigation, municipal, industrial, and hydroelectric generation. Inasmuch as the greatest need for water and power is in the coastal area where water supplies are deficient, river basin planning in the Sierra region must consider potential storage possibilities for stream regulation and exportation of water to the Coastal region in connection with hydroelectric generation. The Peruvian Government has recognized the potential of its water resources and has established a National Water Resources Commission to promote multiple-purpose development.

Hydroelectric development presently is concentrated in the coastal area to serve the metropolitan and industrial demands that have concentrated there. A significant portion of the natural runoff from the Andes to the Pacific has been developed for hydropower and related uses. Waters are being imported from the Amazon drainage to the coastal area from the Maranon and Mantaro River systems, and more such transmountain diversions are underway or envisioned. The Mantaro Project, now partly constructed and in operation, pumps water from the Mantaro River up 600 M (1970 FT) to

"La Problematica Del Desarrollo Electrico Nacional", Conferencia Del Ingeniero Azi Wolfenson U. Presidente Ejecutivo De Electroperu, Lima, July 7, 1977.

"Electroperu Y La Problematica Del Desarrollo Electrico Nacional", Asociacion Electrotecnica Peruana, Lima, 11.01.1978.

"A Preliminary Assessment of the Energy Supply-Demand Situation in Peru", Brookhaven National Laboratory, 1978.

"Preliminary Report on the Energy Resources of Peru", U.S.G.S., U.S.B.M, U.S.B.R., and Argonne National Laboratory, 1978.

"World Energy Resources, 1985-2020", Executive summaries on resources, conservation and demand to the Conservation Commission of the World Energy Conference, 250 pages, IPC Technology Press, London, 1978.

"Impact of the World's Energy Problems on Low Head Hydroelectric Power", by Dr. Ellis L. Armstrong, June 6, 1978.

"The World's Energy Problems and Utah's Future", by Dr. Ellis L. Armstrong, May 13, 1977.

<u>General Overview - Water Supply</u>

The water resources of Peru are tremendous but are subject to wide variations between regions and within regions of the country. Water supplies are scarce in the coastal region where the climate is dry and precipitation is minimal. Agricultural, municipal, and industrial water needs are mostly met from rivers draining the western slopes of the Andes. The majority of these rivers are less than 400 KM (250 Mi) in length and all but a few are seasonal streams that become swollen and turbulent during the summer months, and at other times become dry channels.

The Andes, which comprise the Sierra region, have mountain peaks 6700 M (21,980 FT) above sea level. This lofty mountain range greatly influences the climate and the water supplies of the Coastal and Selva regions. A complex and extensive system of rivers originates in the Sierra close to the continental divide but flows eastward into the Amazon Basin. The largest is the Maranon River, which flows northward from Lake Lauricocha almost to the Ecuadorian border before turning eastward into the Amazon Basin. The Huallaga River rises near the Maranon close to Cerro de Pasca turbulent during the summer months. The coastal agricultural lands are irrigated by water from these streams. East of the divide the streams drain into the Atlantic. Most of these streams follow the southeasterly trend of the mountains which they eventually cross in great canyons and gorges to the eastern lowlands of the Amazon River basin, or Selva, and merge to form the Amazon River.

Between the western and eastern mountain ranges of southern Peru is a high closed basin in which lies Lake Titicaca. This lake is at altitude 3814 M (12,510 FT) above sea level and has a water surface area of 8288 KM^2 (3200 Mi^2). The Peruvian-Bolivian border roughly divides the lake between the two countries. It serves as the main avenue of trade between the two countries.

Sources of Information

Several Peruvian agencies and cooperating authorities have furnished data and reports that have been fundamental sources of information for this report. Some of the principal documents obtained from Peruvian agencies and authorities are listed below, along with references to two preliminary reports compiled by agencies of the United States, one report on "World Energy Resources, 1985-2020", and to two statements recently documented by Dr. Ellis L. Armstrong relating to world energy problems.

"The Water Resources of Peru Problematical and Ordination", Republic of Peru, October 1977.

"Proyecto de Investigacion Microcentrales Hidroelectricas", Direccion De Tecnologia, 1977 (INTINTEC).

"Plan De Electrificacion Nacional", Ministerio De Energia Y Minas, December, 1977.

"Inventario, Evaluacion Yuso Racional Delos Recursos Naturales De La Costs", Oficina Nacional De Evaluacion De Recursos Naturales (ONERN).

"Inventario, De Lagunas Y Represanientos", Oficina Nacional De Evaluacin De Recursos Naturales (ONERN).

home of more than half of the population. The great lowlands east of the Andes make up more than half of the national territory, but they remain sparsely populated and little developed.

The generally recognized geographic regions are identified by name, and their limits are prescribed by legislation enacted in 1960. The Costa region includes the coastal desert and the foothills of the Andes below 2000 meters (6560 FT) elevation. The Selva region includes the tropical rain forest and mountain slopes east of the Andes below the 2000 meter level. Between these two regions are the highlands identified as the Sierra.

The Costa region has a coastline of about 2250 KM (1400 Mi) and is 40 to 80 KM wide (25 to 50 Mi), being broadest in the north where it consists principally of sand dunes that make up the Sechura Desert. Near the Chilean border the low Costa is nearly eliminated by a coastal range with altitudes up to 1070 M (3510 FT).

The Andes form the backbone of South America, extending south from the Caribbean Sea along the entire Pacific coast to Cape Horn. In Peru the Andes are only about 97 KM (60 Mi) wide at the Ecuadorian border, but widen gradually to the south until they become 325 KM (202 Mi) wide near Lake Titicaca. The Andes are divided into western, central, and eastern mountain ranges, or cordilleras, whose summits range in elevation above 6000 M (19,680 FT). The western range of mountains form the continental divide which in places is less than 100 KM (62 Mi) from the west coast. About 50 rivers flow from the Andes to the Pacific across the Coastal region. All rivers flow generally westward except the largest, the Santa River, which runs a hundred miles from south to north through the Callejon de Huaylas Valley before turning westward through a deep canyon to the Pacific. The majority of the Pacific rivers are 400 KM (249Mi) or less in length and all but a few are seasonal streams that become swollen and

INTRODUCTION

This report includes a summary of the water supply and the existing, planned, and potential hydropower developments in Peru. Data supporting this report has been furnished by several Peruvian agencies and cooperating authorities, and from data compiled by the United States Department of Energy, Department of State, and the Department of the Interior. Data from private consulting firms also has been used.

Funds for making this assessment have been provided by the Department of Energy which is investigating possibilities for assisting developing nations to identify their alternative domestic sources of hydropower and fossil fuels, and the less developed sources of solar, wind, biomass and other energy sources.

Description of Peru

Peru has an area of 1,285,220 square kilometers (496,200 Mi^2) and is third largest among the South American countries. It is located entirely in the tropics. The narrow coastal lowlands are temperate in climate, principally because of the presence of the cold Peru or Humboldt Current that flows out of the Antarctic close along the Pacific coastline. These coastal lands receive practically no precipitation.

The middle part of Peru is made up of convoluted ridges and intermontane depressions of the Andes that extend in a southeasterly direction from Ecuador on the north to Bolivia and Chile on the south, roughly paralleling the Pacific coastline. By virtue of their lofty heights, many of which exceed 6000 meters (19,680 FT), these mountains have temperate to cold climatic conditions. East of the Andean crests, the country slopes down from the mountains into the tropical humidity of the vast Amazon jungle lowlands.

The narrow coastal lowlands are the most densely populated part of the country. The extensive valleys and high plains of the Andes that were the center of pre-Columbian populations, however, continue to be the of water from east of the continental divide. Such diversions need storage to regulate widely fluctuating streamflows. There are many natural lakes that are now identified as suitable for storage regulation, which will benefit not only hydropower but irrigation, municipal, and industrial water supplies. Storage sites on many western streams apparently are limited because of sediment and seepage problems and because of existing developments and communities.

5. It is evident that the most difficult problem to solve in Peru is the financing of resource developments. The solution must be based on sound economic principles whether it be for the Peruvian Government or for private enterprises within Peru.

6. Peru has an abundance of basic resources in its water supply, oil, gas, minerals, talent and energy of its people, and in the outstanding beauty of the country. Sound planning and development will insure a promising future.

interests of Peru now and in the future. The Government also has officially supported a comprehensive multiple-purpose approach to water resource development. Thus hydropower generation of electricity appears to be the practical option of greatest importance in Peru.

Atomic energy, where uranium is available, is a practical source of electrical energy, since it would also preserve fossil fuels for other uses and could be constructed near load centers.

Assessment

1. Hydropower should be emphasized in meeting the electrical energy demands in Peru since the potential for expansion is great, and since the water developed for hydropower may then be utilized for needed additional irrigation, municipal, and industrial water supplies which will strengthen and broaden the economic base.

2. Comprehensive-coordinated water resource planning and development should be accelerated in harmony with the directives to the Multisectorial Commission of the National Plan for the Water Resources Ordination. The United States should offer appropriate assistance to this program if the Peruvians seek such assistance.

3. The mini-hydropower program (defined as installations less than about 50 KW), initiated by the Peruvian Institute of Investigation Technological Industrial, should be accelerated to provide electricity to rural areas of Peru not now served. Bringing electrical energy to many small communities where none is now available, will in a small but important way provide means for further growth of the Peruvian economy. It will also provide work for those that are directly served from the hydropower units that are installed. The United States also should offer appropriate assistance to this program if the Peruvian's seek such assistance.

4. The needs for electrical energy are greatest in western Peru along or near the coast. These growing needs can be met by transmountain diversions

Projected Costs of Hydropower

For the period 1977 through 1989, the Minister of Energy and Mines listed needed hydropower developments totalling 2,612.4 MW of increased capacity at a total cost estimated at $2,323 million (1977 dollars). This is for specific power units in the national system. The average cost per kilowatt of capacity is $889, which includes transmission lines as well as the basic hydropower installations and related works, but does not include financing and related administrative costs.

Alternatives

Besides hydropower, there are several alternative sources of electrical energy in Peru. These include further development of thermal energy using fossil fuels in the form of oil, gas, and coal; development of energy from the sun and wind; development of atomic energy although uranium resources may be small; and development of energy from the heat of the earth and from biomass. Production of electrical energy from fossil fuels and from atomic energy has been proven to be practical. Production of energy from the sun and wind has been used for centuries to meet small local needs, but these have not yet been proven as sources of practical commercial electrical energy.

However, the need on the coastal area for water to bolster the food and fiber supply through irrigation and to meet the municipal and industrial demands appears to be as great as the need for electrical energy. Hydropower is the only source of electrical energy that also can supply water to meet other urgent needs. Water that is needed for irrigation, municipal, and industrial supplies can also be used to generate hydropower. The Government of Peru has recognized this and has emphasized the development of hydropower over the use of fossil fuels as being in the best generation of electric power. The imported water is diverted from the Maranon and Mantaro River systems of the Atlantic drainage.

In 1975, the hydroelectric power generation was 5470 gigawatt hours (GWH), or 73.1 percent of the total electrical generation of 7486.2 GWH. Unofficial figures for the year 1977 show that the installed hydroelectric capacity was 1406.5 MW with a corresponding energy production of 5825.3 GWH. The 1977 values for hydroelectric installed capacity and energy are about 55.3 and 71.4 percent of the corresponding total values for the country. The following tables show the installed capacity and energy output for 1977:

YEAR	INSTALLED CAPACITY MW			ENERGY OUTPUT GWH		
	TOTAL	HYDRO	% OF TOTAL	TOTAL	HYDRO	% OF TOTAL
1977	2542	1406.5	55	8155	5825.3	71.4

Potential Demand of Hydro-Energy - 1985-2000

A projection of demand for electric capacity and energy for Peru was made by the Minister of Energy and Mines in December, 1977. That projection was based on sound principles of development at least cost, intensifying development of hydropower in place of thermal power using gas and oil, and the expansion and interconnection of transmission systems to better serve the country. The projected demands and the amount of the demands estimated to be supplied by principal hydropower systems are shown in the following:

YEAR	TOTAL ELECTRICAL DEMANDS*		HYDROPOWER**			
	CAPACITY MW	ENERGY GWH	PERCENT OF TOTAL MW	PERCENT OF TOTAL GWH	CAPACITY MW	ENERGY GWH
1985	3,368*	19,106*	83	86	2800	16,500
1996	6,555*	37,840*	87	92	5700	35,000
2000	8,300**	48,000**	88	94	7300	45,000

* From the National Plan of Electrification of Peru by Minister of Energy and Mines.

** Estimates by U.S. Hydropower Team based on principles endorsed by the Minister of Energy and Mines.

the total area of Peru. The area not included is mostly the lower part of the Selva region. Completion date for this program is March, 1979. Preliminary estimates of the theoretical hydropower potential developed by that program gives the following power potential by principal drainage areas:

ESTIMATED HYDROPOWER POTENTIAL

DRAINAGE	CAPACITY MW
Pacific	29,954.5
Atlantic	163,617.5
Lake Titicaca	557.0
Total	194,129.0

The estimated achievable hydroelectric development, taking into account present economics and problems related to geographic and topographic restrictions, is about 30 percent of the potential, or 58,000 megawatts. The total potential is somewhat smaller than other estimates, but the achievable is larger and is over 40 times the 1977 installed capacity (1406.5 MW) of the present hydropower system, and is 7 or 8 times the year 2000 projected demand.

Present Hydropower Developed

As a developing country in the early stages of industrialization, with an annual income of around $800 per capita, Peru's energy demand is relatively low. The demand for energy will increase as the standard of living improves.

Peru is endowed with many streams which are sources of hydropower to meet a large portion of the electrical demand of the country. Hydroelectric development is concentrated in the Pacific coastal zone to meet the large metropolitan and industrial requirements in that zone. The Tumbes, Piura, Chira, Santa, Chili, Rimac, and Huaura and many other coastal river systems are tapped of natural runoff, or are used as carriers for imported water for irrigation, domestic, municipal, and industrial uses, and for

SURFACE WATER SUPPLY (Millions M^3)

WATERSHED	Total	Actual Usable Volume
Pacific	33,972	20,577
Atlantic	1,437,001	29,732*
Titicaca	23,705	702
Total	1,494,678	51,011

* 8,922 million M^3 (7,233,000 AF) used in Pacific watershed by transmountain diversions.

Over 12,000 natural lakes are scattered throughout the country, of which 6,855 have been surveyed and 5,346 are unsurveyed. Of the lakes surveyed 862 have catchment areas of 4 KM^2 (1.5 Mi^2) or more. A total of 186 of these lakes having a total usable capacity of 3,028 million M^3 (2,455,000 AF) have either been developed, or are being developed for one or more uses. An additional 342 lakes having a total usable capacity of 3,953 million M^3 (3,205,000 AF) are under investigation. Both actual and potential regulation afforded by lakes under development and lakes under study coupled with high heads provide the ingredients for additional hydropower development.

Potential Hydropower

During the late 1960's the Government of Peru with the assistance of the Federal Republic of Germany undertook an assessment of the future demands for electric energy and the hydroelectric potential of Peruvian water supplies. The assessment and projects were carried forward to year 1985. This previous assessment is now being updated. The German consulting firm of Lahmeyer International is providing technical assistance and working with Peruvian personnel on the elaboration of an optimal expansion program for the electrical supply systems of the country. This assessment covers 110 of the hydrologically important basins of the country in the Pacific, Atlantic, and Lake Titicaca watersheds. These river basins comprise about 54 percent of

ASSESSMENT OF WATER SUPPLY AND HYDROPOWER - PERU

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SUMMARY

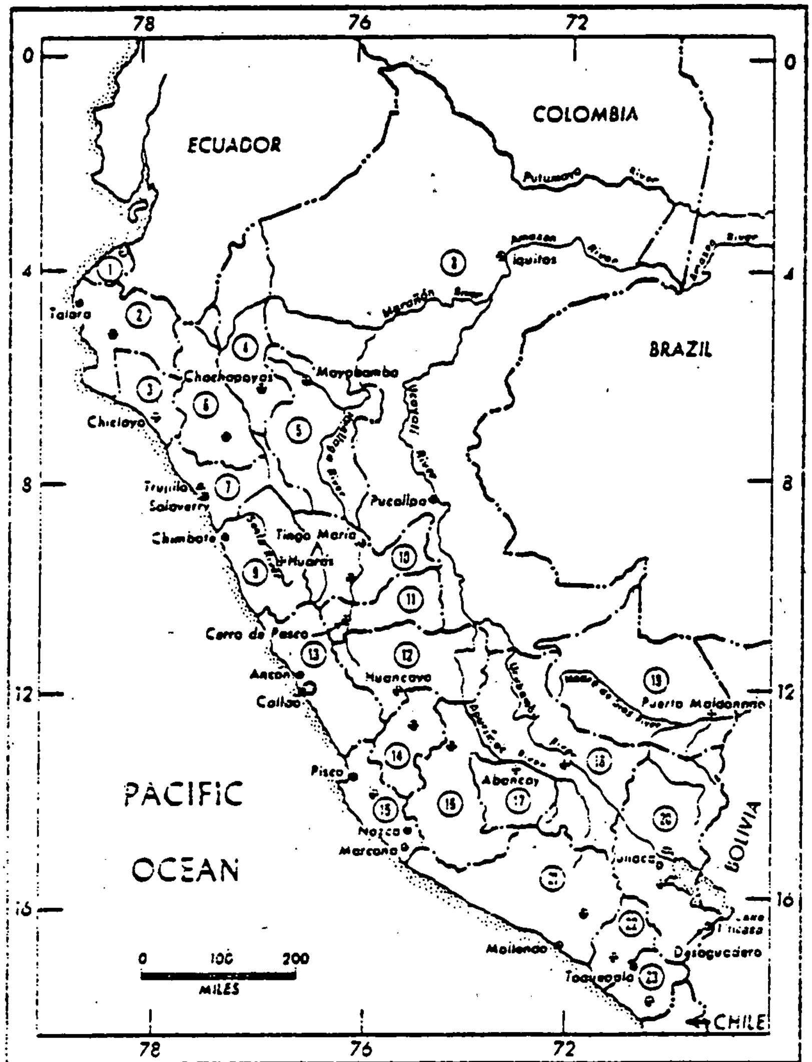
The Department of Energy is investigating possibilities for assisting developing nations to identify their domestic energy resources, including hydropower, nuclear and fossil fuels, as well as the less developed sources such as solar, wind, geothermal and biomass. This report includes a summary of the water supply and the existing, planned, and potential hydropower developments in Peru. Data supporting the report has been furnished by several Peruvian agencies and cooperating authorities, and from data compiled by the United States Department of Energy, Department of State, and the Department of the Interior.

Water Supply

Mean annual rainfall in Peru ranges from near zero in the coastal desert area to as high as 3400 mm (134 in) at Tingo Maria in the high Selva region. The Coastal region is dependent on streamflow in rivers draining the western slopes of the Andes. Present water supplies in the Coastal region are approaching full development for irrigated agriculture, municipal, industrial and hydropower needs. Future development in the coastal area will largely depend on water imported from the eastern slopes of the Andes.

The water supply and head for potential hydropower development in Peru is great. The total annual surface water supply, as estimated by the Peruvian National Office of Evaluation of Natural Resources (ONERN), averages about 1.5×10^{12} cubic meters (1,212 million AF). About 3 percent of the total has been identified as practical for near future development. The surface water supplies are divided between the Pacific, Atlantic and Titicaca watersheds as follows:

PERU

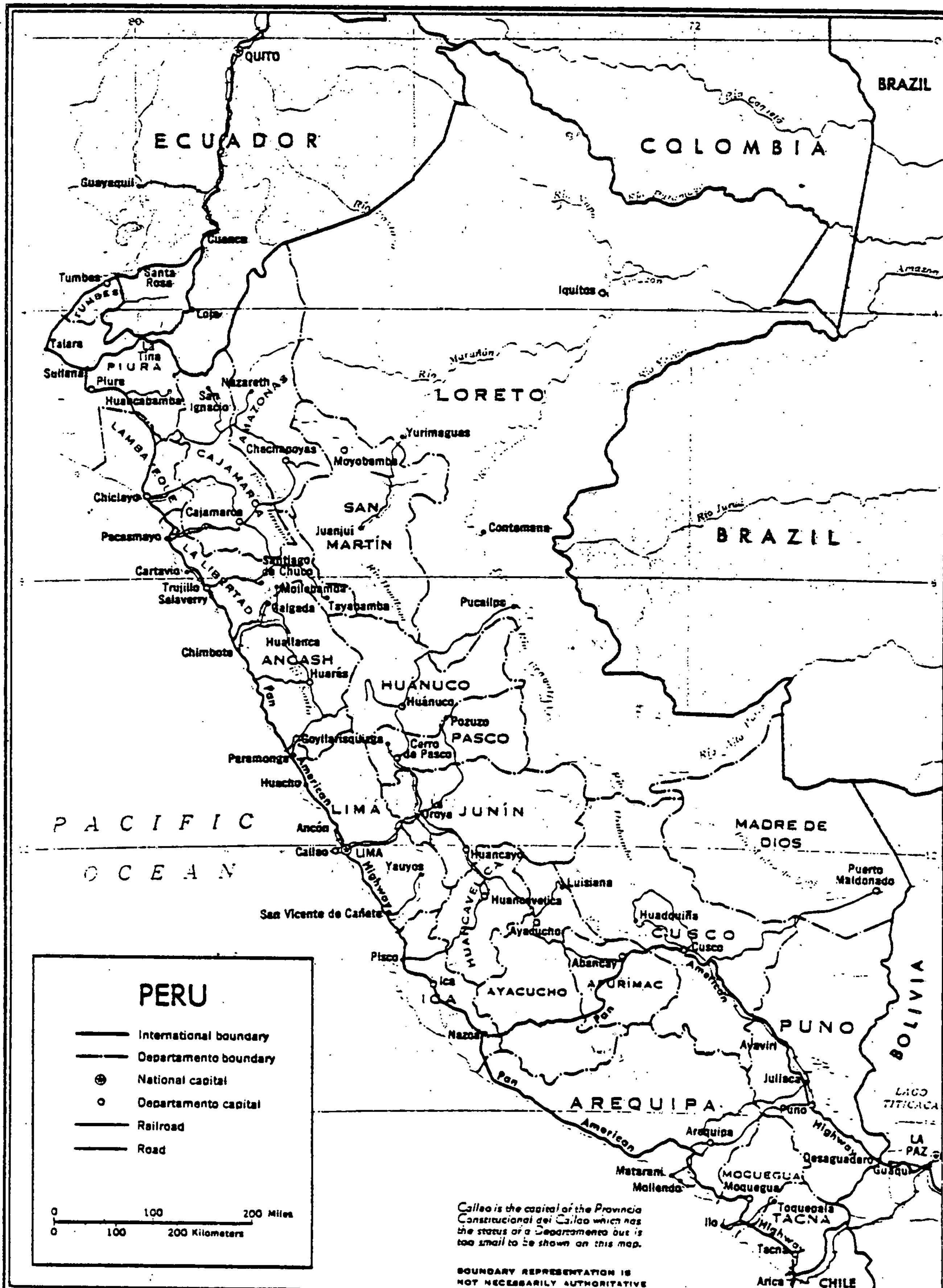


DEPARTMENTS

1 TUMBES
2 PIURA
3 LAMBAYEQUE
4 AMAZONAS
5 SAN MARTIN
6 CAJAMARCA
7 LA LIBERTAD
8 LORETO
9 ANCASH
10 HUANUCO
11 PASCO
12 JUNIN
13 LIMA
14 HUANCAVELICA
15 ICA
16 AYACUCHO
17 APURIMAC
18 CUZCO
19 MADRE DE DIOS
20 PUNO
21 AREQUIPA
22 MOQUEGUA
23 TACNA

NOTE--Departments are indicated by number. Capitals are same name as departments except where otherwise indicated. In either case, the symbol ⊕ indicates capital city. ⊙ indicates other major cities. ◯ indicates national and provincial capital.

MAP OF PERUVIAN DEPARTMENTS



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July 21, 1978.

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WASHINGTON, D.C. 20585

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

POSTAGE AND FEES PAID
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FIRST CLASS MAIL