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

Volume 1 of 4 Vols.
Executive Summary, Main Report
and Appendices

August 1979

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

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JOINT PERU/UNITED STATES REPORT

ON THE

PERU/UNITED STATES

COOPERATIVE ENERGY ASSESMENT

VOLUME I

EXECUTIVE SUMMARY, MAIN REPORT AND APPENDICES

AUGUST 1979

Prepared by
representatives of the
Ministry of Energy and Mines
Republic of Peru

and the

Department of Energy
United States of America

with the assistance of the
U.S. Department of State.

FOREWORD

In Fiscal Year 1978, the United States, in cooperation with the Government of Peru, conducted a comprehensive assessment of Peru's energy resources, needs, and uses and developed several alternative energy strategies that utilize the available resources to meet their energy requirements. This work was performed during the pilot phase of the International Energy Development Program that was initiated by President Carter in September 1977. This assessment was a collaborative effort by a team of U.S. and Peruvian experts in energy resources and technologies, development economics, and energy systems planning and analysis. The Department of Energy managed the U.S. component of the assessment under the overall policy guidance of the Department of State.

This report on the assessment was jointly prepared by the U.S./Peruvian expert teams. Volume I contains the executive summary, the main report, and five appendices of information that directly support the integrated energy supply and demand analysis. Volumes II through IV contain eleven annexes that present the contributions of the participating technical specialists.

This report is being distributed to interested agencies within the Executive Branch of the United States Government and to U.S. Congressional committees and staffs. In addition, copies have been provided to the Government of Peru for their distribution and use and to institutions such as the World Bank and the United Nations. Additional copies of the report can be obtained from the National Technical Information Service under the terms of the GPO price schedule set forth on the inside of the front cover of the report.

Any questions about the report should be directed to:

Director
Country Energy Assessment Program Office
Office of International Affairs
U.S. Department of Energy, Stop 7F-031
1000 Independence Avenue, S.W.
Washington, D.C. 20585

October 1, 1979

This Assessment was conducted jointly by Peruvian and U.S. technical experts on the basis of information available from a number of sources both in Peru and the United States. The Assessment, its assumptions and its observations do not necessarily reflect the official policy of either government. Neither the Government of the United States, the U.S. Department of Energy, nor any of their contractors, subcontractors, or their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any contained information.

Joint Peru/United States Report

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EXECUTIVE SUMMARY
PERU/U.S. COOPERATIVE ENERGY ASSESSMENT

1.0 INTRODUCTION

Over a six month period during 1978, Peruvian and U.S. representatives and technical specialists worked collaboratively to assess both the energy resources that will be required by Peru through the year 2000 and the energy demand and supply options which are now or could be available to Peru over that interval. The description of overall energy demand and supply in Peru that is presented here is a central portion of a comprehensive information base on which the Government of Peru can base future energy plans and policies.

The report on the cooperative assessment consists of a main report, five appendices containing materials that directly support the analysis, and annexes that present the contributions of the technical specialists to that analysis. This Executive Summary describes the setting for the energy assessment in Peru, briefly explains what was done, and summarizes the principal insights that can be drawn from it.

2.0 THE ENERGY CHALLENGE PERU FACES

Energy development is an important element in the challenge that Peru will face over the balance of this century. As Peru moves to fulfill its need for expanded and secure energy supplies, the process will be complicated by a number of related considerations, such as regional diversity, population growth and migration, and economic issues.

Peru is both large and geographically diverse, and the great differences between its three major regions present a number of obstacles, not only to performing an integrated national energy assessment, but also to implementing several of the apparent solutions that emerge. For example, the Andean mountain ranges that separate the coastal plain, the central Peruvian Sierra, and the jungle regions in the western Amazon basin offer both the promise of vast hydropower reserves and the problem of extremely difficult natural barriers over which these resources must be transported or power transmitted. In addition, many of the energy resources in Peru are located in regions that are remote from centers of demand. That is, most of the undiscovered oil reserves are believed to lie beneath the Amazon rain forest in eastern Peru, while most of the petroleum is consumed in urban centers on the coastal plain and in the Sierra. These examples highlight a situation that will present difficulties to energy development in Peru, especially after the year 2000: as new energy sources become more and more remote, increasingly expensive means to move the primary (oil, gas, or water) or secondary (electricity) energy forms will have to be implemented.

Population growth and trends in rural-to-urban migration are other influences that exacerbate energy development problems in Peru. The year 2000 projections for Peru assume that the total population will have doubled (from 16 million in 1976 to 33 million in the year 2000) and that the rural population will remain almost constant (from 10 million in 1976 to 11 million at the end of this century). This anticipated population growth, which is based on official Peruvian population estimates, has a major impact on projections of energy requirements for Peru. The use of commercial fuels will increase, both on an absolute and a relative (percentage) basis. This follows because the urban population relies primarily on commercial fuels and can be expected to continue to do so. Moreover, while the rural population now depends heavily on noncommercial energy sources, it can be expected to make increasing use of commercial fuels. This increasing reliance on commercial fuels will have a substantial effect on the levels of domestic and foreign investment that will be required to develop energy resources.

Although the abundance of its indigenous energy resources offers Peru a wide variety of opportunities, realizing them has been difficult in a fiscal climate characterized by economic stagnation, spiraling inflation, and a large external debt. While Peruvian gross domestic product (GDP) grew at an average annual rate of 6 percent in the period 1970-1976, the Peruvian economy suffered at the same time a sequence of international and domestic deficits that precipitated a financial crisis in 1977 and 1978. These deficits were accompanied by high inflation, falling production, and overvaluation of the Peruvian currency (sol) in foreign exchange markets. These internal economic and management problems, aggravated by declining world prices for Peru's principal export (copper) and a large and growing external debt, brought the Peruvian economy to a virtual standstill.

However, the Government of Peru has recently taken strong measures to remedy these economic problems. Among these have been efforts to cut imports, budget cutbacks and a reduction in the real money supply to fight inflation, and continuing adjustments of the currency exchange rate. Peru has also succeeded in restructuring its external debt so as to relieve pressure on its balance of payments over the short- and medium-term. In addition, world copper prices have recovered since the beginning point where it exceeds domestic consumption. These factors have helped to convert Peru's balance of payments deficit into a surplus. The recessionary trend of falling production appears to have reversed, which helps to create a more favorable climate for further investment and growth. As a result, this assessment examines Peru's future requirements for energy resources in the broad context of a continued improvement in the economic situation and a return to sustained growth in productive potential.

3.0 THE COOPERATIVE ASSESSMENT PROCESS

The assessment was conducted by a team of Peruvian and U.S. specialists in a number of disciplines, including engineering, energy resources, energy technologies, development economics, and analytical methods. The Government of Peru established its portion of the assessment team by Ministerial Resolution, a translation of which is appended to this summary. Table ES-1, which is also attached, lists the U.S. members of the team. The team used the best available data to analyze Peru's economic development base and energy resource situation, to identify energy supply and demand options for the future, and to develop alternative energy supply and utilization strategies. Specialists from the U.S. Geological Survey assessed the prospective availability of energy resources and energy-related minerals. An energy supply/demand network, developed by the Brookhaven National Laboratory of the U.S. Department of Energy, was used to describe energy production and consumption in 1976 and to balance projected energy supply and demand for 1985 and the year 2000. Other specialists were drawn from the Peruvian Government and the U.S. Department of Energy and its contractors to examine possible applications of existing and advanced energy supply and utilization technologies.

4.0 THE ASSESSMENT PRODUCTS

This assessment is a technical energy analysis, rather than a policy study. It provides a comprehensive picture of projected energy demand in Peru through the year 2000, as well as an evaluation of the quality of the basic fuels and energy resources that are potentially available to meet that demand and some indication of the extent of those resources. It also includes several alternative projections of the energy supply/demand balance for the year 2000, which could serve as a basis for the Government of Peru to prepare energy strategies.

To establish a benchmark against which the effects of alternative energy policies and strategies could be measured, a possible future configuration of the energy supply and demand situation in Peru was developed as a 'Reference Case'. The Reference Case is based on the integration of historical trends in the Peruvian economy and energy system with identified Peruvian government and private sector plans that will affect future energy use and supply.

The assessment also examines several alternative energy planning strategies, including aggregated estimates of the capital and operating costs, manpower, and equipment that would be needed for energy supply facilities in each. It identifies factors which should be considered in the evaluation of various options and offers suggestions about the next steps that Peru could take to initiate selected courses of action.

The report also highlights a number of uncertainties in both the process and the results, most of which stem from inadequate data on resource levels and insufficient integration in current plans. In addition, it offers suggestions about next steps that build on this assessment to continue more comprehensive and systematic energy planning in Peru.

The assessment is not intended to be an energy plan. That is, it neither attempts to optimize the planning options and strategies that were examined, nor offers value judgments about those alternative courses of action. On the other hand, through the cooperative assessment process, the Government of Peru has been exposed to and shared in the use of the analytical tools, evaluation factors, and data that have been used in the assessment. This has provided an information base on which Peru planners can formulate energy plans and develop comprehensive energy policies.

5.0 ASSESSMENT INDICATIONS

Among the major observations which can be drawn from the assessment are the following:

1. Peru's future energy demand is dominated by the energy needs of the industrial and transport sectors. Reduction of energy demand through increased reliance on energy-efficient devices and processes has been shown in other countries to be one of the most cost-effective ways to enhance a country's capability to meet its energy needs. It is believed this can be done without sacrificing economic growth objectives. Accordingly, careful examination of ways to reduce the prospective demand for petroleum in Peru's industry and transport sectors should be given high priority in any continuing energy planning in Peru.

2. Petroleum will continue to be the dominant element in Peru's energy system through the year 2000. Although Peru currently exports oil, domestic demand is expected to surpass production by the mid-1980's. Increases in exploration activity and/or shifts in current trends could mitigate this situation toward the end of the century.

3. Current indications are that increasing amounts of Peru's future oil production will come from oil fields that lie in the Amazon jungle areas in the eastern region of the country. The ultimate potential of the jungle regions could be quite large, although a more intense exploratory effort will be needed to confirm the extent of these reserves. To this end, Peru has offered attractive production-sharing arrangements to foreign oil firms to compensate for the high risk and high exploration costs of building an assured base of oil reserves and expanding its oil production capability. Under these arrangements, the contractors receive a specified portion of the oil produced as compensation, although Peru retains the option to buy some or all of the contractor's share at world oil market prices. As a result, a significant portion of future petroleum demand in Peru may be filled by oil purchased at high prices, even though that oil may have been produced within the physical boundaries of the country.

4. Peru has other, additional energy resources that could be exploited to supplement its energy supply and offset the demand for oil. Indeed, the effective development of these resources could enable Peru to be self-sufficient in oil supplies by the year 2000.

5. Hydropower is the key energy resource for electricity generation in Peru over the foreseeable future. The current electric system expansion plans of ElectroPeru (the state-owned electric utility) envision that the bulk of new generating capacity will be hydroelectric. Many opportunities also exist to use small hydro systems to supply small amounts of power to isolated communities, although this would largely satisfy new (rather than existing) demand for electricity.

6. A major constraint on the use of Peru's hydroelectric potential at levels substantially greater than those envisioned in current plans is posed by the financial implications of the great distance and difficult terrain between prospective hydro sites on the eastern slopes of the Andes and the principal energy demand centers on the Pacific coast. Nonetheless, since the hydroelectric energy potential is so vast, Peruvian energy planners and policy makers should continue to search for economic ways to utilize this potential.

7. Better knowledge of both the extent of Peru's coal reserves and the feasibility of their development and use is needed, and such efforts warrant priority attention in Peru's near-term energy programs. Recent reductions in the subsidies given to the petroleum sector should provide an improved economic incentive for the use of domestic coals in industry and for power generation.

8. The traditional uses of biomass, especially firewood, currently account for approximately one-third of total energy consumption in Peru and satisfy almost all of the energy needs of the rural population. This level of use has caused minimal adverse environmental effects to date, and the situation is not expected to deteriorate, largely because population shifts to urban areas are anticipated and noncommercial fuel supplies are adequate. However, the introduction of more energy-efficient conversion methods could free labor for more productive uses than fuel-gathering and improve rural living standards. In addition, the process of shifting from traditional fuels to commercial fuels (e.g., kerosene) in rural areas deserves further study to clarify the future demand for petroleum products.

9. The application of new and existing biomass conversion technologies could provide opportunities for the expanded use of currently available forest and other biomass resources, such as agricultural residues and animal wastes, in an economically productive and environmentally sound fashion. The forests of the Amazon basin in eastern Peru are an immense biomass resource, but their location poses major logistic, economic, and environmental barriers to their effective exploitation.

10. Certain regions of Peru offer some potential for near-term applications of solar technologies. In areas with good solar insulation, these could provide domestic water heating in cities and towns, and electric power to remote villages and mining installations. It seems likely that some of the power needs in remote areas could also be met with wind energy systems, although insufficient data were available to allow a reasonable assessment of its potential. Since hot water is still a relative luxury in many areas in Peru, and the power needs of isolated villages are small, direct solar systems will not make a significant contribution to reducing Peru's heavy dependence on oil over the period to the year 2000. This is also true, in part, because many applications of direct solar technologies will supply newly-created energy demand, rather than substitute for current demand for commercial fuels.

11. Although the Government of Peru is actively considering nuclear energy systems and is pursuing a balanced nuclear technology program, it now envisions no use of nuclear power plants before the year 2000. Peruvian efforts over that interval will focus on research, radioisotope applications in medicine, agriculture, and industry, and the construction of a research reactor at a recently authorized research center. Current plans call for the decision on the construction of Peru's first nuclear power plant to be made some time before 1995, but only if nuclear energy enjoys economic advantages over hydroelectricity. If that decision is favorable, construction of the plant would start in 1995. The need for Peru to consider the use of nuclear power in the period beyond the year 2000 will continue to depend upon its ability to develop its vast hydroelectric resources effectively and economically.

12. The assessment was done on a national basis. It attempts to take into account the more significant regional differences that exist in Peru and their major impacts on energy planning at the national level. However, because the energy resource and demand situations in each of the three major regions of Peru and their subregions differ so greatly, more detailed assessments of regional energy needs, uses, and resources will be necessary to provide additional information in support of Peruvian energy policy and planning activities. This will also support current policies that are directed toward decentralization of economic activities, since such detailed regional assessments would provide improved projections of local energy needs and resources.

13. While current Peruvian efforts in energy planning are sound, further effort should be devoted to assuring the integration of energy plans with those of other economic sectors (e.g. industry and transportation) on a continuing basis. One means that could enhance the current degree of integration in Peruvian energy planning would be to establish an energy planning institute that would build on the base established through this assessment.

SUMMARY

Peru is blessed with indigenous energy resources that could meet its needs well beyond the year 2000. Significant opportunities for increased effectiveness in the current and projected use of energy exist in the transportation and industry sectors. More work is needed both to confirm its oil and coal reserves and to determine the ability of its large hydroelectric resources to provide economically competitive energy. The use of direct solar and wind energy technologies is expected to make only a limited contribution by the end of this century. Effective use of its indigenous energy resources through existing and well-proven energy technologies should make it unnecessary for Peru to utilize the nuclear option until some time after the year 2000, if then.

Because significant differences exist between the geographic regions of the country, Peru should undertake detailed regional planning studies to support comprehensive national energy planning efforts. In addition, greater integration of Peru's energy analysis and planning activities with its broader development plans and programs is needed. Continuation of the measures that were recently initiated to correct the causes of Peru's financial difficulties and related economic stagnation is crucial to the successful implementation of its energy plans.

MINISTERIAL RESOLUTION

MINISTERIAL RESOLUTION

Lima, August 11, 1978

WHEREAS:

It is imperative to achieve the power supply needs as imposed by national development in the short-, medium-, and long term, by making use of all resources available in the country, in an integrated and rational manner;

For this purpose the Ministry of Energy and Mining is currently carrying out a Long-Term Energy Plan for 1978-1990, comprising prospects for the year 2000, in which viable alternatives for the development of energy will be considered;

For the formulation of the Long-Term Energy Plan, base studies are presently being carried out, among which are the National Energy Budget, which will allow the definition of an Integral Energy Policy, and the technological research and development projects aimed at fulfilling energy requirements in the short-, medium-, and long-term;

In order to implement the aforementioned technological research and development projects that will permit a future use of alternate sources of energy, international foreign assistance is required;

At the present time a team* of experts from the Brookhaven National Laboratory and the U.S. Geological Survey, commissioned by the Department of Energy of the United States of America, is in our country to study a technical cooperation program for the use of alternate sources of energy;

It is therefore relevant that a national counter-part Commission be established in order to coordinate all activities aimed at facilitating and making feasible all tasks involved in the above-mentioned technical cooperation program;

With the agreement of the Director General:

* Editorial Note: Other U.S. experts on the team in Peru at that time were from the U.S. Department of State, the Argonne National Laboratory, Sandia Laboratories, Armstrong Associates, Arthur D. Little, Inc., Gordian Associates, and the University of Florida.

IT IS DECREED THAT:

Article 1. - A Commission is hereby established, which will act as a national counter-part and will coordinate all activities required in order to carry out and facilitate the implementation of the Technical Assistance Program as outlined by the Department of Energy of the United States of America for technological research and development of alternative energy sources aimed at fulfilling the energy needs of the country in the short-, medium-, and long-term.

Article 2. - The above-mentioned Commission shall be made up of:

Eng. Ricardo Saettone Dodds	Superior Director, Ministry of Energy and Mining, who will preside.
Eng. Jaime Fernandez Concha	Advisor for Mining and Geology of the Ministry of Energy and Mining.
Eng. Hermann Montalvan P.	Director General, Sectoral Office for Planning of the Ministry of Energy and Mining.
Eng. Jorge Aguinaga D.	Head of the Electrical Planning Area of the Sectoral Office for Planning of the Ministry of Energy and Planning.
Eng. Ricardo Giesecke	National Energy Budget Project expert.
Eng. Fridolino Veliz	Engineer, General Bureau of Electricity of the Ministry of Energy and Mining.
Eng. Aurelio Cossio	Director of General Geology, INGEOMIN.
Eng. Jose M. Carasco	Planning Coordinator, PETROPERU.
Eng. Cristobal Chang Say	Manager, Nuclear Electricity Project, IPEN.
Eng. Justo Yanque M.	Division Chief of Energy Research, INIE.
Eng. Wilfredo Salinas	Chief, Integration and Project Studies Division of the General Bureau of Hydrocarbons of the Ministry of Energy and Mining.

To be recorded and disseminated,

(seal and signature)

Table ES-1

The United States Energy Team

<u>Position</u>	<u>Name</u>	<u>Organization</u>
<u>MANAGEMENT</u>		
Team Leader	William Porter	Department of Energy
Deputy Team Leader	Frederick Ordway	Department of Energy
Technology Team Leader	Glen Wensch	Argonne National Laboratory
Demand Team Leader	Philip Palmedo	Brookhaven National Laboratory
Executive Officer	James Keyser	Brookhaven National Laboratory
Administrative Offices	Charles Cruik	Argonne National Laboratory
<u>TECHNOLOGY SPECIALISTS</u>		
Solar	Peter Teagan Eric Farber	Arthur D. Little, Inc. Consultant provided by U.S. Agency for International Development
Fossil Energy	Zane Murphy	U.S. Department of Energy
Nuclear Energy	Edward Purvis	U.S. Department of Energy
Hydropower	Paul Willmore	Armstrong Associates
Biomass	Eliseo Mariani Alan Poole	Marelco, Inc. Consultant provided by U.S. Agency for International Development
Energy Systems	Jack Allentuck Andres Doernberg Steven Kyle	Brookhaven National Laboratory Brookhaven National Laboratory Brookhaven National Laboratory
Energy Facility Costs	J. Michael Gallagher Tony Bowles	Bechtel National, Inc.
Conservation-Industry	Kenneth Stern Barry Tunnah	Bechtel National, Inc. Gordian Associates Gordian Associates
Conservation- Transportation Development Specialist Manpower	Peter Smith John Reedy Richard Roman	Arthur D. Little, Inc. Arthur D. Little, Inc. Argonne National Laboratory

Table ES-1 (continued)

The United States Energy Team (continued)

<u>Position</u>	<u>Name</u>	<u>Organization</u>
<u>RESOURCE SPECIALISTS</u>		
Geothermal	Robert Fournier	U.S. Geological Survey
Oil and Gas	Robert Mattick	U.S. Geological Survey
	Keith Yenne	U.S. Geological Survey
Uranium	Edwin Noble	U.S. Geological Survey
Coal/Energy-related	Wilds Olive	U.S. Geological Survey
Minerals	Robert Hobbs	U.S. Geological Survey
Water	Stuart Schoff	U.S. Geological Survey
Hydropower	John Steele	Armstrong Associates
Biomass	Jerome Harper	Argonne National Laboratory
	Wayne Smith	University of Florida
Solar	Eldon Boes	Sandia Laboratories

1.0 INTRODUCTION

1.1 Purpose and Scope of the Cooperative Assessment

The Government of Peru and the United States have undertaken this collaborative assessment of the current and projected energy situation in Peru to advance the state of Peruvian energy planning activities. The assessment is intended to enhance the capability of the Government of Peru to identify the complete scope of available energy alternatives and to support a comprehensive examination of practicable ways in which it could pursue those options.

The assessment process involves developing a better understanding of the existing and potential energy resources that are indigenous to Peru and applying systematic and objective approaches to project future energy demand. It also includes using sound methods to evaluate the feasibility of energy demand and supply options that are or may become available to support energy development in Peru, and collaborating to identify and develop a number of comprehensive energy strategies.

Each of these energy strategies illustrates a way in which Peru could exploit its indigenous resources and apply available energy technologies to meeting its energy needs through the year 2000. At the same time, each strategy combines the available options to attain a specified energy development objective, such as increasing the use of Peruvian coal in lieu of petroleum, or accelerating the application of solar and other renewable-resource energy technologies.

The energy options that make up each strategy are of two general types: resource options and technology options. Typical of the former are petroleum, coal, hydropower, geothermal, solar and uranium. As for the latter--technology options--they could include, for example, solar energy for water heating or crop drying, wind-driven irrigation pumps, and energy-efficient industrial processes. The options that may be of interest are very diverse, ranging from expanded resource extraction to increased end-use efficiency; from highly centralized technologies (typified by large-scale, central station electricity production) to decentralized, household- or village-level energy systems; and from systems that use commercial fuels, such as petroleum, to those that use noncommercial fuels, such as crop residues.

The analysis that leads to the definition of energy strategies must consider three groups of factors: (1) the eventual role that the various options may play; (2) costs, benefits, and impacts of the options; and (3) the steps that must be taken to implement the options. This assessment addresses these issues for each of the energy options that are of potential importance to Peru.

This assessment is not a policy study. It offers no recommendations as to which options and policies should be emphasized, since the formulation of national energy policy involves political and social factors that lie

outside the scope of this analysis. Nevertheless, an objective analysis of energy options, in the context of national economic development and future energy demand, can provide a solid foundation for the formulation of national policies. Thus, it is believed that the data, the analyses, and the analytical approach used in this assessment can eventually make a significant contribution to future national energy policies for Peru.

The preliminary nature of this assessment must be emphasized. As discussed below, this kind of analysis involves considering and projecting the entire picture of national energy supply and demand well into the future, and such a task is full of uncertainties, at best. In the time available for this assessment, it has been possible to take only the first step toward a complete and objective analysis of energy strategies and options for Peru. The authors are hopeful that subsequent efforts will build on this foundation.

1.2 Collaborative Nature of the Assessment

The assessment was conducted as a collaborative effort by a team of U.S. experts under the management of the U.S. Department of Energy (DOE) and a Peruvian counterpart team working within the management structure of the Ministry of Energy and Mines. A fundamental principle of the operation was to establish a close working relationship between the U.S. team and the Peruvian management and technical counterparts. The primary objectives of this close counterpart relationship were threefold:

- o To combine the skills of Peruvian and U.S. specialists so as to obtain better insight and information as to energy resource, production, planning, and utilization capabilities in Peru.
- o To acquaint Peruvian officials with the information collection, analysis, and evaluation methods being employed by the U.S. team so that they could apply them in later energy analysis and planning activities, if they should choose to do so.
- o To gain from the Peruvian counterparts better insight into energy analysis and planning factors that must be considered or emphasized in developing countries vis-a-vis considerations that are more pertinent to developed countries.

The U.S. team consisted principally of: (1) management, who provided administrative and analytical support and liaison with the Peruvian counterparts; and (2) specialists in various technical, economic, and institutional areas who conducted interviews and collected the background information and performed the analyses. The Peruvian counterparts were organized as a Commission formed by Ministerial Resolution 0431-78, dated August 11, 1978, and approved by Ricardo Saettone Dodds, Director Superior of the Ministry of Energy and Mines (see Appendix A.1). The members of the

Commission represented a wide selection of organizations involved with and interested in energy activities. Their senior technical level and broad experience clearly indicated the extent to which the Government of Peru endorsed the joint Peru-U.S. energy assessment study.

The U.S. team directed their data collection efforts in Peru (Appendix A2) to four categories of information:

- o Basic energy and energy-related resources, both nonrenewable and renewable.
- o Energy demands in the industrial, agricultural, residential/commercial, and transportation sectors.
- o Energy production capabilities, including fuel production and processing, energy conversion (primarily to electrical energy), and fuel and energy transport and delivery.
- o "Crosscutting" development factors such as: social, economic, and institutional considerations; financing requirements and capabilities; supply facility costs, equipment, and manpower requirements; and manpower capabilities.

Data collection, integration, and analysis was conducted by technical specialists drawn from several sources, including DOE program organizations, the Argonne National Laboratory, the Brookhaven National Laboratory, and private U.S. companies and consultants under contract to DOE or the two laboratories.

Following the data collection activities by the U.S. team in Peru and a preliminary integration, analysis, and review carried out in the United States, a six-man Peruvian team led by Director Superior Saettone, came to the U.S. to participate in a joint review of the analysis and to strengthen it as needed (Appendix A.3). (This same group of officials worked closely with the U.S. team from April through October, collecting information and preparing portions of this report.) Throughout the entire exercise, active consultation was maintained with a number of governmental and financial agencies in the United States and Peru.

1.3 The Analytical Procedure

1.3.1 The choice of analytical methods: The objectives of the study, and the limitations of time and resources, significantly influenced the choice of analytical methods used in this assessment². Additionally, a clear requirement was that the analytical approach permit the objective evaluation of a wide range of possible energy and energy-related options.

The analytical method described in this section satisfies these basic needs. It is straightforward, but can incorporate as much technical detail

as desired. The method is based on techniques used at Brookhaven National Laboratory (BNL) to analyze U.S. energy issues. In the U.S. version, a full set of economic linkages has been developed³. In the Peru case, the method did not include this direct interactive linkage to a national macro-economic model, since the extensive data requirements of the U.S. version could not be met. A set of linkages more appropriate to Peru is currently being developed (at BNL).

1.3.2 The basic approach: The analysis calls for the construction of a view of the energy supply-demand situation that would exist in the future under current national economic development policies (the Reference Case). A consistent, detailed picture of the future energy system of the country under these assumptions is created for 1985 and 2000. An accounting is made for each of these years of such factors as energy resources consumed, capital investment required, and (under certain assumptions regarding oil production) the implied imports or exports of petroleum.

In addition, an evaluation is made of the energy resource base of the country and the rates at which these resources could be developed and used. The evaluation considers both traditional, nonrenewable resources, such as oil, coal, natural gas, and nuclear fuels, as well as renewable resources, typified by hydropower, solar, and wind resources. Once the resource base has been established, a comparison can be made between the resource requirements implied by the Reference Case and the resources that can be produced domestically to satisfy those requirements. In this way, the needs for imports or the possibility of exports can be determined.

A set of resource and technology options is then defined. These options could include the development and use of coal resources, the increased use of solar energy, or measures to improve energy-efficiency in selected industrial activities, for example.. Each option is defined in terms of its economic, energy, and resource characteristics, along with its possible level of implementation (including the fuels or technologies for which it will substitute) in 1985 and in 2000. Then, through adjustment of the energy supply-demand balance, one can estimate the effects of implementing the option on the energy supply requirements and capabilities. From these estimated effects, one can also estimate the relative changes in supply facility costs and equipment or requirements and manpower.

In the interest of analytical convenience, several strategies have been defined, each of which incorporates a number of options. For example, the accelerated renewable resource strategy includes wind turbines, biomass fuels, and other renewable resource options. Their combined effect on the use of petroleum is then calculated. The analysis results in a view of the impact of energy development on current policies and trends.

1.3.3 The Reference Energy System: The analytical framework used for the analysis is based on the Reference Energy System (RES) approach developed by the Brookhaven National Laboratory for the Department of Energy.⁴ RES is a framework that integrates a set of estimated energy demands, energy conversion technologies, fuel mixes, and energy resources into an overall energy supply/demand balance. The RES format consists of a pictorial network diagram that indicates both energy flows and the associated conversion efficiencies of various technologies employed in energy production, transmission, distribution, and utilization systems. The energy balance for Peru in 1976 is shown in Figure 1.3-1. Similar balances have been developed for selected energy strategies (and the Reference Case) for the years 1985 and 2000.

As illustrated in the figure, each path through the energy system diagram indicates a possible route for the flow of energy from an energy resource to a given demand category. Alternate paths and branches reflect the substitutability of various resources and technologies for one another. The energy flowing through each step or process is shown above the line representing the activity. The numbers in parentheses represent the efficiencies, or relative effectiveness, of the processes. Both commercial and noncommercial energy resources are dealt with in the system.

The construction of a supply/demand balance using this network starts with the projection of the underlying determinants of energy demand, for example, future industrial output in terms of tons of steel produced or vehicle-kilometers to be traveled. The more critical of these are indicated at the right-hand side of the figure. The energy processes used to support those activities are then specified along with the fuels used. Then, progressing to the left in the energy system diagram, the various energy conversion and transport technologies are indicated with their associated efficiencies.

In choosing technologies and fuels for energy supply, consideration is given to the availability of various fuels and to any established capital construction plans. This process is judgmental, making use of available engineering, economic, and resource information. The process employed in this assessment does not include any optimization techniques. Such techniques were not considered to be applicable in this case, given the wide variations in the availability of data.

The analytical approach is readily adaptable to optimization techniques in the future, so that the analysis of options affecting very specific uses of energy (e.g., water heating) could be performed. This requires that the demand portions of the energy balance be developed in considerable detail. Such detail was not always available for Peru.

FIG 1.3-1 REFERENCE ENERGY SYSTEM FOR PERU, 1976

Moreover, the supply/demand balance had to be projected well into the future, leading to major uncertainties in the extrapolation of current data. This being the case, the projected balance for Peru should not be interpreted as a prediction of the future, but rather as a mechanism for technology and energy analysis.

To facilitate the analysis of options, a computer model was developed⁵ that corresponds to the RES for developing countries. Known as the LDC Energy System Network Simulator (LDC-ESNS), it can be used in association with an economic and environmental data base to analyze the impacts of options and strategies once their levels of implementation are determined.

1.3.4 Manpower, equipment, and financial analysis: The financial, manpower, and equipment requirements of the Reference Case and alternative strategies are calculated using the Bechtel Energy Supply Planning Model (ESPM). This model was originally developed for the National Science Foundation by the Bechtel Corporation to provide a quantitative tool for the analysis of energy options in the United States. Each strategy (including the Reference Case) entails a different mix of energy supply and conversion options, including onshore and offshore oil, coal, geothermal energy, and hydroelectric power. The implementation of these or other options requires differing quantities of capital, manpower, and equipment. ESPM provides a systematic way to determine the total direct resources required to build and operate the energy supply facilities needed to implement each scenario.

A central feature of the ESPM is an extensive engineering data base on all of the resources required to design, construct, start up, operate, and maintain energy supply and transportation facilities.

Forty-six energy facilities are identified for the energy sector of Peru. These represent typical installations likely to be built during the time frame of the study. Costs for these facilities are based on estimates of Peruvian and expatriate labor rates and labor productivities, and estimated local and foreign purchases of material and equipment. Fourteen of the estimates are derived from U.S. data, assuming Peruvian facilities of the same size. The remaining sixteen estimates are derived by first scaling down data on comparable U.S. facilities, using economy of scale exponents, and then translating the results to account for Peruvian labor and materials. Sixteen facilities are estimated for this effort, exclusively on data obtained in Peru. Major data items reviewed in Peru include:

- o Cost per kilowatt for electric power plants,
- o Cost per kilometer for transmission lines,
- o Cost per hole for oil and gas wells,

- o Peruvian and expatriate labor wage rates,
- o Peruvian and expatriate labor productivity factors,
- o Cost contingency percentages,
- o Availability of unpaid labor for micro-hydro facilities,
- o Local availability and cost of materials and equipment, and
- o Regulations on the import of various materials and equipment, and their related costs.

The data consists of about 40 line items of costs of manpower, materials, equipment, and miscellaneous cost, for both construction and operation of each of the facilities. Also included are construction schedules, estimates of the number of manpower hours required, and estimates of various materials and equipment required for each facility. In total, there are about 300 "items" of information for each of the 46 facilities. Two such sets of data have been developed, the first showing total resources required, and the second indicating that portion of the various resources (including manpower) that Peru would have to import.

The ESPM stops its consideration of cost, manpower, and materials at the point at which energy is delivered in some form to the final user. No attempt is made to compute costs for energy-using devices (e.g., a blast furnace), because the wide range of technologies involved would make it impractical.

1.4 Transfer of Methods and Data to Peru

In addition to this report and its appendices and annexes, a number of analytical techniques, the supporting data, and related training support are being provided to the Government of Peru. These include:

- o The energy system analysis structure utilized in the cooperative energy assessment and all of the pertinent data for each strategy examined;
- o The LDC-ESNS model adjusted to the processes and technologies of importance to Peru; and
- o The data base that was used to prepare the estimates of energy supply facility cost, equipment, and manpower requirements for each of the strategies, modified to reflect conditions in Peru.

The transfer of these materials and participation in their application should enable subsequent Peruvian energy planning activities to build more readily upon this assessment.

Notes and References to Section 1

1. The term "commercial" energy generally refers to energy forms normally actively traded in developed country markets, such as oil, gas, coal, and electricity. The primary categories of "noncommercial" energy are wood, agricultural wastes, and animal dung. The term "noncommercial" is in fact a misnomer, since there are monetary markets for these fuels. In some contexts, the term must be extended to include human and animal power. Other terms sometimes used for "noncommercial" are "traditional," "primitive" (vs. "modern"), or "nonconventional" (vs. "conventional").
2. A more complete description of the analytical methodology is given in "An Analytical Framework for the Assessment of Energy Resources and Technology Options for Developing Countries," BNL-50800, February 1978, Policy Analysis Division, Brookhaven National Laboratory, Upton, New York.
3. See, for example K. C. Hoffman and D. W. Jorgenson, "Economic and Technological Models for Evaluation of Energy Policy," Bell Journal of Economics, Autumn, 1977. Also, BNL-222895, Brookhaven National Laboratory, Upton, New York.
4. The Reference Energy System approach was developed at Brookhaven National Laboratory in 1971, for energy R&D assessment, and has been extended for various analyses since that time. See M. Beller, Ed., "Sourcebook for Energy Assessment," BNL-50493, December 1975, Brookhaven National Laboratory.
5. A computer model to facilitate option analysis with the RES is described in A. Reisman and R. Malone, "Less Developed Countries Energy System Network Simulator LDC-ESNS-A Brief Description," BNL-50836, February 1978, Brookhaven National Laboratory, Upton, New York.
6. "The Energy Supply Planning Model," Volume I: Model Structure and Use; Volume II: User's Manual and Appendices;" M. Carasso, J. M. Gallagher, K. J. Sharma, J. R. Gayle, R. Barany, Bechtel Corporation, NTIS No. PB-245 382, PB-245 383, August 1975; also, see "Resource Requirements, Impacts, and Potential Constraints Associated with Various Energy Futures," J. Michael Gallagher, Ronald Barany, Paul F. Paskert, and Ralph G. J. Zimmerman, Bechtel Corporation, NTIS No. PAE-3794-6, 9, March 1977 and March 1978 Annual Reports.

2.0 THE ENERGY SITUATION IN PERU

2.1 The Economic Context and Background

2.1.1 General considerations: Peru occupies the west coast of South America between Ecuador on the north and Chile on the south. To the northeast it is bounded by Colombia and to the east and southeast by Brazil and Bolivia. The country's land area is about 1.3 million square kilometers.

Geographically (Figure 2.1-1), Peru can be divided into three distinct regions. The arid coastal plain bordering the Pacific Ocean comprises about 12 percent of Peru's land area and ranges in width from 17 to 170 km. This region contains the country's principal urban areas. The coastal plain is bounded along its eastern perimeter by mountainous terrain ranging in altitude from 800 to 2000 meters. The Andean Cordillera Occidental forms the continental divide. Together with the intersecting Cordillera Central and the Cordillera Oriental, it dominates the country's hydrography and has important consequences for the development of its hydropower potential. The high plateau between the Cordilleras forms a Sierra which accounts for about 27 percent of the country's area. The eastern slopes of the Andes forming the western edge of the Amazon basin are humid and covered by dense rain forest. This area is known as the Selva (jungle) and is sparsely inhabited. It has acquired added importance in recent years as a significant area of petroleum exploration.

Peru's population was approximately 16 million in 1976 and was growing at an estimated annual rate of 2.8 percent in the 1970's. It is split between urban and rural areas roughly in the ratio 65:35. In 1976, the coastal plain was inhabited by 27 percent of the total population, with the sierra and eastern Andean slopes accounting for 60 percent and 13 percent, respectively. The principal metropolis, Lima-Callao, had approximately 20 percent of the total population, and that percentage continues to increase.

2.1.2 The domestic situation: The 1977 gross domestic product (GDP) and per capita income are estimated at US \$12.4 billion and US \$748, respectively.² The sectoral composition of the gross domestic product is shown in Figure 2.1-2. Major economic activities in the geographic regions of Peru are displayed graphically in Figure 2.1-3.

2.1.2.1 Agriculture: The total cropland in Peru is 3.6 million hectares, of which about one-third is irrigated. Most of this land is located in small coastal valleys. Since rainfall in most of Peru's coastal area is negligible, irrigation is essential for agricultural production. This region, where most of the country's large urban centers are located, produces almost two-thirds of Peru's total value of agricultural output; for centuries it has been a primary source of food production. The main crops are maize, sugarcane (a major export crop), rice, and cotton. In contrast to the coastal area, the sierra region, where most of Peru's rural

FIGURE 2.1-1 MAP OF PERU

FIGURE 2.1-2 SECTORAL COMPOSITION OF GROSS DOMESTIC PRODUCT

SOURCE: Reference 3

FIGURE 2.1-3 ECONOMIC ACTIVITY MAP OF PERU

population is located, is characterized by subsistence agriculture. The climate there is unfavorable, and the soils and water availability is poor. Cereals, tubers, and livestock are the main products.

Up to 1968, most of the land was held in large, privately-owned estates (latifundia) operated by wage-labor or tenant farmers. The military regime that took power in 1968 instituted a program of land reform, and most of the plantation and large estates have since been converted to peasant cooperatives.

Over-irrigation and inadequate attention to drainage and land contouring have caused severe problems of salinity and waterlogging in about a fifth of the irrigated area. This situation has led to a decline in production. The World Bank is providing technical and financial assistance to the Peruvian government for projects designed to alleviate the problem.

Agriculture constitutes about 13 percent of Peru's GDP and employs more than 40 percent of the labor force. In addition, industries based on agriculture account for 30 percent of employment and 40 percent of value added in manufacturing. Growth in agricultural production has been stagnant for the past three years, showing low (under one percent), and even negative, growth rates. For the last 15 years, agricultural output, especially food production, has lagged behind population growth, and food imports currently place a serious burden on the balance of payments. Unless growth can be increased to at least the rate of population growth, food imports will continue to place increasing pressure on the balance of payments.

2.1.2.2 Fishing: The Peruvian fishing sector is counted as an industry in national accounts. This is largely because the production of fishmeal from anchovies has been an important activity in Peru for several decades.

This industry is gradually recovering from the 1972 crisis when unfavorable spawning conditions (due to unpredictable ocean currents) led to a sudden, unexpected decline in the anchovy catch. The government has since started to return the fishing fleet it acquired before the crisis to the private sector so as to minimize the drain on the government budget caused by the poor catches in the 1970's. There is currently a restriction on fishing to allow the severely depleted stock of anchovies to grow to levels that will sustain commercial operations. Oceanographers at the Peruvian Instituto del Mar urge a continuation of the restriction at least through 1980.

2.1.2.3 Mining: Since ancient times, Peru has been known for its rich mineral resources. It was the gold hoards of the Inca empire that spurred the Spanish conquistadores to their conquest of what is now Spanish-speaking Latin America.

The mining sector accounts for about 54 percent of total Peruvian exports. The major export and the principal product of Peru's mines is copper, followed by silver, lead and zinc, and gold and iron ore. Peru is the leading silver producer in South America and ranks fifth among world producers. It is the world's fourth largest lead producer and ranks fifth in zinc. A large variety of other non-ferrous metals are produced as well. The government has stressed expansion of downstream processing capabilities in order to increase domestic value added. As these facilities come into operation, the composition of Peru's mineral exports will shift increasingly from ore to refined metals production.

There are currently three major mining organizations in Peru, CentrominPeru, MineroPeru, and Southern Peru Copper. Both Centromin and MineroPeru were created recently and are owned by the government. After the assumption of power by the present government in 1968, the thrust of government policy in the mining sector has been to ensure state control of national resources while encouraging expansion of production and refining capacity with the aid of foreign capital and technical expertise. Centromin was created as an autonomous company owned by the state after the nationalization in 1974 of the Cerro de Pasco Corp., the largest mining company in Peru. MineroPeru was organized in 1974 and owns most of the attractive but as yet undeveloped mineral deposits in Peru. Some eight of these holdings were previously foreign-owned. Southern Peru Copper Corporation is the only major private company still operating in the Peruvian copper industry. HierroPeru (the state iron mining company) was formed in 1975 after nationalization of the Marcona Mining Company.

MineroPeru is authorized to refine and market all mineral products, although some private companies are allowed to refine metals other than copper. These three major enterprises and HierroPeru account for 65 percent of mining sector output. About 60 medium-size private companies, producing partially refined ores, account for another 30 percent of output, while some 1,000 small, labor-intensive mines make up the remainder. Much of the product of these medium- and small-scale mines is sold to Centromin for further refining.

2.1.2.4 Industrial production: In 1976, food processing accounted for 24 percent of industrial production. The principal components of this industry are fishmeal production, sugar refining, grain milling, production of edible and inedible fats and oil, and meat packing. In terms of the value of its output, the chemical industry is the second most important. Metallurgical industries experienced high growth in the early 1970's and are expected to continue growing through the 1980's. A small automobile industry produces some 10,000 to 17,000 vehicles annually. Currently, production is down due to depressed demand and increased costs. However, finalization of Andean Pact assignments for joint auto production should provide a stimulus. Other industries include chemicals and pharmaceuticals, cement, building materials, pulp and paper, and rubber. Handicraft production both on a commercial and non-commercial basis is also significant. The distribution of manufacturing industries is shown in Figure 2.1-4.

NOTE:

DOES NOT ADD TO 100.0% DUE TO ROUNDING

REFERENCE:

CUENTAS NACIONALES – INSTITUTO NACIONAL
de ESTADISTICAS

FIGURE 2.1-4 DISTRIBUTION OF MANUFACTURING INDUSTRIES. 1976

2.1.2.5 Economic trends: In the period 1970-1976, Peru's GDP grew at an average annual rate of almost 6 percent. However, the rate masks a sequence of international and domestic deficits that precipitated the economic crises of 1977 and 1978. The deficits were accompanied by inflation, by falling productivity, and by chronic overvaluation of the Peruvian sol in the foreign exchange market. These distortions, aggravated by collapsing world prices for Peru's principal exports, brought the Peruvian economy to a virtual standstill. The 1977 GDP showed negative growth (-1.0 percent) according to the Instituto Nacional de Planificación (INP, the National Planning Institute).⁴ The situation worsened in 1978, with manufacturing and construction being among the hardest-hit sectors of the economy. Sagging demand and widespread under- and unemployment have inhibited expansion of manufacturing output. Serious inflation (32.4 percent in 1977, and over 70 percent in 1978) has made large inroads into per capita real income. It has been a particularly difficult problem for export-based industries whose profit margins are squeezed by rising production costs and foreign exchange rates that have not kept pace with domestic inflation.⁵ There are signs that the situation is stabilizing in 1979. The refinancing of the external debt (see below), as well as the elimination of the balance of payments deficit by the end of 1978, are encouraging, as is the government's success in adhering to its stabilization program.

The central element in Peru's current economic situation is the still-growing external debt, which has risen from \$1.5 billion in 1973 to \$8.27 billion in 1978. The interest payments on this sum amount to some \$500 million in 1978, which is more than 25 percent of foreign exchange earnings. Repayments of principal elevated the total 1978 debt service to \$972 million.⁶ In November of 1978, the Peruvian government completed a \$2 billion refinancing of the foreign debt. This will lessen financial pressure on the government, as repayments are delayed to the 1980's. Current payments are limited to 35% of export earnings, as opposed to the 60% that would have been required without refinancing.

Changes in the gross domestic output, in terms of the various productive sectors, are shown in Table 2.1-1; the composition of GDP in the period 1976-1978 is shown in Table 2.1-2.

The Peruvian economy is expected to show low rates of growth over the next five years due to the depth of the current recession (see Appendix D). It is anticipated that historical rates of growth (5 percent per annum) will resume by the mid-1980's, as the effects of current and planned economic policies are felt. Mining and mineral exports will play the leading role in renewed economic growth as new mines and downstream processing facilities come on line during the next five to seven years. Growth in nontraditional exports will also be important.

Economic recovery in Peru will probably be increasingly dependent on effective governmental action that is needed to counteract the unfavorable consequences that have arisen from earlier subsidies and controls.

Table 2.1-1
Yearly Percent Growth in Gross Domestic Product⁷

	1974	1975	1976	1977
Basic Productive Sectors	(+7.3)	(+2.5)	(+4.0)	-0.1
Agriculture	+2.3	+1.0	+3.3	-0.1
Fishing	+35.9	-15.2	+19.9	-7.9
Mining	+3.7	-10.9	+8.9	+25.4
Manufacturing Industry	+7.5	+4.7	+4.2	-4.7
Construction	+22.0	+16.8	-2.8	-10.0
Other Sectors	(+6.3)	(+4.2)	(+2.1)	(-2.0)
Total = Gross Domestic Product	+6.9	+3.3	+3.0	-1.0

Note: Growth rates in parentheses are aggregate.

Table 2.1-2
Composition of Gross Domestic Product, 1976-1978⁷
(Percent)

	1976	1977	1978
Private consumption	73.6	74.3	75.0
Public consumption	11.7	14.7	12.9
Investment	20.4	13.2	9.7
Exports	12.1	13.2	14.7
Less imports	-17.7	-15.3	-12.3
Gross domestic product	100.0	100.0	100.0
Of which, gross domestic saving is	14.8	N/A	N/A

2.1.3 Foreign trade: Exports account for almost 15 percent of Peru's GNP; they are essential in maintaining its ability to import food and manufactured goods, as well as financing its growing debt. Copper, other minerals, and fishmeal are Peru's principal exports. The decline in both world copper prices and Peru's fishmeal production has led to severe balance-of-payments difficulties, and default on private bank loans due for payment in 1978 at times seemed a real possibility. However, copper prices recovered in 1978, in a large part due to disruptions in copper production in other countries (most notably Zaire). In addition, Peru is currently pursuing an economic policy of severe austerity and import reduction along lines laid out by the International Monetary Fund. These factors have alleviated Peru's balance-of-payments position substantially. (Further reduction of imports will be difficult, as major portions of them consist of food and other essential items.)

In 1977, Peru's trade balance showed a deficit of \$438 million. Peru converted this deficit into a surplus in 1978, largely due to greatly increased mineral exports and decreased imports, particularly petroleum. Shifts in the country's balance of payments over the period 1974-1977 are shown in Table 2.1-3. Composition and value of 1976 exports are shown in Figure 2.1-5, and Table 2.1-4 shows Peru's principal imports and exports in descending order of value for the year 1974.

Table 2.1-3

Balance of Payments, 1974-1977^a (millions of U.S. dollars)

	1974	1975	1976	1977
Exports, FOB	+1,503	+1,291	+1,359	+1,726
Imports, FOB	-1,909	-2,390	-2,100	-2,164
Trade Balance	- 406	-1,099	- 741	- 438
Net on Services & Transfers	- 402	- 439	- 451	- 488
Balance on Current Account	- 807	-1,538	-1,192	- 926
Long-Term Capital	+ 895	+1,135	+ 675	+ 674
Basic Balance	+ 88	- 403	- 517	- 252
Short-term Capital and Errors & Omissions	+ 194	- 173	- 351	- 98
Balance of Payments (-indicates increase)	- 282	+ 576	+ 868	+ 350
Net International Reserve Position (end of year)	+ 693	+ 116	- 752	-1,102

^a Source: U.S. Department of Commerce, "Foreign Economic Trends and Their Implications for the United States", 1977, Washington, D.C.

FIGURE 2.1-5 EXPORTS, 1976 (\$ U.S. MILLION)⁸

Table 2.1-4

Principal Peruvian Imports and Exports^a, 1974

Imports	Exports
Machinery	Metals and metal manufactures
Metals and metal manufactures	Processed foods and beverages
Chemical products	Mineral products
Mineral products	Textile products
Vegetable products	Precious metals
Plastic materials and products	Vegetable products
Transport equipment	Live animals and meats
Paper machinery & raw materials	Chemical products

^aIn decending order of value. Peru's principal trading partners are the U.S., Japan, and the European Economic Community. Source: Ref. 8

2.2 Energy Resources and Production

The following sections discuss each of Peru's energy resources along with past and present trends in their production. For convenience, the resources have been divided into three categories: (1) fossil fuels; (2) nuclear fuels; and (3) renewable resources.

2.2.1 Fossil Fuels

2.2.1.1 Oil and Gas: Estimates of Peru's oil reserves made by Petroleos del Peru, the Peruvian national oil company, are summarized in Table 2.2-5.

Table 2.2-5
Petroleum Reserves in Peru

Reserve Category ^a	Reserves, Barrels x 10 ⁶
Measured reserves	560
Indicated reserves	160
Inferred reserves	<u>95</u>
Total identified reserves	815

^aDefinitions of terms applied to oil and gas resource appraisal are contained in Appendix B.1

Source: Communication from Rafael Antesana, Planning Manager, Petroleos del Peru.

Of the measured reserves, 380 million barrels are located in the Amazon region and the remainder in the Talara basin (both onshore and offshore) in northwestern Peru. The indicated reserves refer to the oil that could be produced by secondary recovery methods from the onshore part of the Talara basin. (Figure 2.2-6 shows the location of the oil and gas deposits in Peru.).

A higher estimate of Peru's oil reserves, amounting to 1,095 million barrels, has been made by USGS specialists who participated in the assessment. The main difference between the U.S.G.S. figures and those of Petroperu arises from the higher U.S.G.S. estimates of the potential for secondary recovery in Talara.

Estimates of undiscovered recoverable oil resources vary widely. On the basis of recent exploration, officials of Petroperu have agreed that undiscovered recoverable oil resources probably amount to approximately 26 billion barrels. However, rather than estimating Peru's total hydrocarbon resources, the objective of this assessment is to arrive at a basis for estimating possible oil production for the years 1978-2000. For this purpose, we categorize significant undiscovered recoverable resources as those that could be exploited by existing or near-term technology within the time frame covered by this study. Taking this consideration into account, USGS specialists arrived at estimates of significant undiscovered recoverable resources, ranging from 2060 to 3240 million barrels. The major portion of the resources, are believed to exist in the Amazon region south of the currently producing oil fields.

Oil Bearing Areas of Peru

FIG 2.2-6

Peru's known reserves of natural gas are small. The measured gas reserves of the Talara basin are estimated by Petroperu to amount to one trillion cubic feet but, according to USGS scientists, the complexity of the area makes this figure highly uncertain. In the Ucayali basin, in the Amazon region, the Aquaytia gas field is estimated by Petroperu to contain subeconomic resources of 318 billion cubic feet. Estimates of undiscovered gas resources range widely, from 1.3 and 11.5 trillion cubic feet.

Historical crude oil production, imports, and exports, are shown in Figure 2.2-7. Despite an increase in crude oil production from 62,000 barrels per day in 1965 to 91,000 barrels per day in 1977, Peru shifted from being a net oil exporter to being a net oil importing country in the late 1960's. However, with the completion of the trans-Andean pipeline in 1977 and the northern branch pipeline in February 1978, domestic production again exceeded consumption and had attained a level of 163,100 barrels per day by mid-1978. Crude oil production is expected to stabilize at a level of about 200,000 barrels per day through the early 1980's and then gradually decline as currently producing fields deplete, unless new discoveries spur fresh output.

Peru has five major refineries with a total crude oil refining capacity of 180,000 barrels per day. This capacity is believed adequate to handle the aggregate demand for refined products through 1985. In 1976, residual oil accounted for 31 percent of total refinery output, followed by gasoline (29 percent), diesel oil (18 percent), and kerosene (12 percent).

The production of natural gas in Peru is of minor importance in comparison with oil. Production amounted to about 73 billion cubic feet in 1977. Almost all was associated gas from the oil fields of the northwest.

2.2.1.2 Coal: Coal deposits are reported to occur in 18 of Peru's 24 departments and include coal ranging in rank from lignite to anthracite. The promising deposits are located in central and northern Peru.

No attempt has yet been made to classify Peru's coal reserves on a nationwide basis according to internationally accepted procedures. Limited information on reserves is available for areas that were formerly mining sites or are currently under investigation. Four coal fields, in particular, appear to have considerable potential as sources of fuel and metallurgical (coking) coal. They include Alto Chicama and Santa Valley in the north, and Oyon-Gazuna and Jatunhuasi in central Peru. Table 2.2-6 contains a tabulation of Alto Chicama's reserves of coal. Reserves of the other fields are considerably smaller.

None of Peru's coal resources is currently being exploited. According to official statistics, coal was last mined in Peru in 1973, when a small amount of anthracite was produced. The domestic market for coal had

FIG 2.2-7 CRUDE OIL PRODUCTION, IMPORTS, AND EXPORTS

SOURCE: SEE APPENDIX B.1

dwindled because Government subsidies made oil products economically more attractive. The current rise in oil prices should make the exploitation of Peru's coal resources competitive again.

Table 2.2-6

Alto Chicama Coal Reserves⁹

Category	Reserves (metric tons)
Proven	25,222,741
Probable	34,478,764
Possible	<u>211,137,134</u>
Total	270,838,639

2.2.2 Nuclear Fuels: Limited exploration for uranium has not led to any discovery to date of economically exploitable deposits of uranium in Peru. However, large areas of the country, particularly the eastern region, remain to be explored. An ongoing United Nations Development Program funded in association with the Instituto Peruano de Energia Nuclear (IPEN, Peruvian Institute of Nuclear Energy) includes a project of field investigation to determine regions favorable for uranium occurrences. This study is part of Peru's Nuclear Plan for the period 1976-1981. A copy of this plan is included in Annex-6 to this report.

2.2.3 Renewable Resources

2.2.3.1 Hydropower: The potential head and flow of water for hydropower in Peru is very large.¹⁰ Table 2.2-7 contains preliminary estimates of the hydro power potential of the principal drainage areas, the Pacific, the Atlantic, and Lake Titicaca. (A more detailed account of the potential of individual river basins is contained in Ref. 10).

Table 2.2-7
Estimated Hydro Power Potential¹⁰

Drainage	Mw
Pacific	29,954.5
Atlantic	163,617.5
Lake Titicaca	<u>557.0</u>
Total	194,129.0

Approximately 70 percent of this potential is not exploitable due to geographical, topological and economic reasons, and the existence of competing uses for water, such as irrigation, further restricts the achievable hydroelectric capacity. However, even taking these factors into account, it is clear that a very considerable amount of potential hydro resources remain that could be developed to meet Peru's future electricity demand. Most of the estimated hydro power potential is associated with the rivers on the eastern side of the Andes range that drain into the Amazon basin. Since this region is remote from the main load centers of coastal Peru, diversion of rivers and/or extensive high voltage transmission lines would be necessary to translate the achievable hydro potential into reality. At present, transmountain diversions of water from the Marañon and Mantaro River systems of the Atlantic watershed are used to supplement the available water supplies in the Pacific area.

2.2.3.2 Biomass: Wood (from natural forests, plantations, and orchards), agricultural crop residues, and animal wastes comprise Peru's biomass resources. Most of the energy needs of the rural population are met by firewood, the dominant biomass resource in use. In particular geographic areas, animal wastes (dung) and agricultural residues (sugar-cane bagasse) are also used in significant amounts. Biomass can have an increased importance in meeting Peru's future energy needs if a well-managed program of resource development and utilization is implemented.

The forest resources of Peru are immense. However, 99 percent of the forest area is located in the Amazon jungle region, and there are significant environmental, economic, and logistic barriers to the extraction, conversion, and transport of these resources to the major energy-consuming areas in coastal Peru.

Firewood foraged from forests and farms is a major source of fuel for the rural population of Peru. Estimates in this report (see Appendix B) that are based on an analysis of the energy requirements of rural households lead to a figure of about 138 quadrillion joules of firewood use in 1976. This represents a little over one-fourth of the primary energy consumption from all sources in Peru for that year. As far as other biomass resources are concerned, sugar cane bagasse is largely used to serve the process heat and electricity requirements of the sugar industry and as a feedstock for paper manufacture. The residues of other agricultural crops do not appear to be utilized for energy purposes at present. Dried animal wastes are used as a fuel in settlements in the Sierra highlands.

2.2.3.3 Solar and Wind:¹¹ There are several areas in southern Peru, such as Piura, Arequipa, Moquegua and Puno, that have very good solar resources, with insolation levels of about 2500 kwh/m²-yr (9×10^9 joules/ m²-yr). Much of the Sierra region has moderate solar availability, while coastal regions, such as the Lima area, have poor solar resources. Moreover, data on Peru's solar energy resource base is inadequate. Preliminary estimates made in this assessment (see Appendix B.1) are based on records of duration of "bright sunshine" maintained by the Servicio Nacional de Meteorología y Hidrología (SENAMHI, the National Meteorological and Hydrologic Service).

Good wind resources exist along the southern coast of Peru. Other areas appear to show only marginal wind availability. However, a much wider effort on collection of data needs to be mounted before an adequate assessment of wind resources can be made.

2.2.3.4 Geothermal:¹² For the purposes of this assessment, Peru's geothermal resources can be subdivided into inferred resources and speculative resources. (See the footnote to Table B.1-16 in Appendix B.1 for a definition of these categories). The existence of these resources is indicated by the chemical and physical character of the hot springs in many parts of the country, through a broad knowledge of the geologic characteristics where economically exploitable geothermal resources tend to occur, and by analogy to demonstrated geothermal reserves in northern Chile. The inferred resources are all found in southern Peru in areas of recent and active volcanism. Speculative resources exist in central and northern Peru, generally in a narrow belt of hot spring activity within the Cordillera Occidental.

2.3 Energy Consumption Patterns

2.3.1 Resource Consumption Trends: The energy resource consumption, by type and relative market share, from 1965 to 1976, is shown in Figure 2.3-8. Total resource consumption in Peru grew at an average annual rate of 3.2 percent in the last decade, reaching 538×10^{15} joules in 1976. During this period, per capita consumption remained stable at about 34 x

10^9 joules.* Consumption of commercial energy resources grew at a faster rate, 5.1 percent, than total energy growth; its share increased from about 56 percent in 1965, to 68 percent in 1976.

Like most other countries, Peru depends heavily on petroleum for its energy needs. The consumption of oil, which grew at an average annual rate of 4.6 percent during the last decade, amounted to nearly three-fourths of total commercial energy consumption in 1976. Of this consumption, nearly two-thirds was obtained from domestic production, and one-third from imports of crude (imports of refined products are small). Ecuador supplied most of the imported crude, followed by Venezuela and Colombia.

Hydro power was the fastest-growing energy source between 1965 and 1976, with an average annual growth rate of 7.3 percent. Its relative share of commercial energy (expressed as fossil fuel equivalent) was estimated at 19 percent in 1976. A brief discussion of the role of hydro power in Peru's electric sector is given in Section 2.3.3.

The use of natural gas and coal is inadequately documented (with the exception of imported coke from Japan and bituminous coal from the United States), making it difficult to obtain an accurate picture of historical trends. However, it is clear that neither accounts for a significant portion of commercial energy resource use. The shares of natural gas and coal in commercial energy consumption have remained at approximately 5 and 3 percent, respectively, over the past decade.

Noncommercial fuels accounted for about one-third of Peru's total energy resource consumption in 1976. Firewood is the predominant noncommercial fuel (over 80 percent); the rest is made up of agricultural and animal wastes.

2.3.2 Sectoral final demand: The sectoral breakdown of commercial energy consumption by final users is available from sales data of Petro-Peru and ElectroPeru. Table 2.3-8 summarizes the use of commercial energy by sector. In 1976, 308×10^{15} joules of commercial energy were consumed, three-fourths of which went to the transportation and industrial sectors. In addition, an estimated 162×10^{15} joules of firewood and other non-commercial fuels were consumed in the residential and commercial sector, and 10.5×10^{15} joules of oil were used in petroleum refineries.

Breakdowns of the energy consumed in the transportation, mining and manufacturing, and residential and commercial sectors are given in Figure 2.3-9, Table 2.3-9, and Table 2.3-10, respectively. Further details on the individual sectors can be found in Appendix B.3.

2.3.3 The electric sector: Electricity consumption grew at an average annual rate of 6.5 percent between 1964 and 1976 (see Figure

*This is approximately 10 percent of per capita consumption in the United States.

FIGURE 2.3-8 ENERGY CONSUMPTION. 1965-1976.

Table 2.3-8
Commercial Energy Demand, 1976
(10¹⁵ Joules)

	Oil	Natural Gas	Coal	Hydro ^a	Electricity	Total Direct Use
Residential	33.6	—	—	—	9.4	43.0
Industrial	72.8	16.2	11.0	—	14.8	114.8
Transportation	117.3	—	—	—	—	117.3
Agriculture	8.4	—	—	—	1.1	9.5
Electricity Generation	23.8	4.2	—	20.8	(25.3)	23.5 ^b
Total Demand ^c	255.9	20.4	11.0	20.8	—	308.1

^aTaken as electricity generated.

^bTaken as total resources consumed by utilities less electricity generated

^cTotal resource consumption is obtained by adding noncommercial fuels, refinery consumption, and the hydro adjustment for fossil fuel equivalence to the total demand shown here.

TOTAL = 110.3 (10^{15} JOULES)

FIGURE 2.3-9 TRANSPORTATION ENERGY CONSUMPTION* BY MODE, 1976

SOURCE: SEE APPENDIX B.3

Table 2.3-9
Energy Consumption in Mining and Manufacturing, 1976
(10¹⁵ joules)

	Coal	Oil ^a	Electricity
<u>Mining and non-ferrous metals</u>	1.6	19.9	7.1
<u>Industry</u>			
Iron and Steel	6.0	1.8	0.7
Cement	--	9.2	0.9
Petrochemicals	--	0.2	0.1
Fertilizers	--	5.3	0.6
Chemicals	--	1.5	1.0
Fishing	--	9.0	--
Glass	--	4.9	--
Food Processing	--	6.3	--
Textiles	--	3.1	--
Paper	--	3.1	--
Construction	--	1.8	--
Others	--	20.6	3.9
TOTAL	7.6	86.7	14.3

^a Includes oil consumption for self-generated electricity

Source: Annex-2

Table 2.3-10
Residential and Commercial Energy Consumption, 1976
(10¹⁵ joules)

Fuel	<u>Residential</u>				<u>Commercial</u>	Total
	Cooking/ Heating (urban)	Cooking/ Heating (rural)	Lighting	Other		
Electricity	0.71	-	.86	5.22	2.60	9.39
Kerosene	16.28	6.28	5.63	-	-	28.19
LPG	5.35	-	-	-	-	5.35
Firewood	-	138.0	-	-	-	138.0
Other	-	24.0	-	-	-	24.0
Total	22.34	168.28	6.49	5.22	2.60	204.93

Source: Appendix B.3

2.3-10), reaching 7,911 GWh in 1976. The principle electricity consumers are shown, along with their respective consumption levels, in Figure 2.3-11. The industry and mining sectors consumed nearly half of the total consumption and residential uses, the other major consuming sector, accounted for 17 percent. In terms of the regional distribution of electricity consumption, nearly half of the electricity was consumed in the vicinity of Lima.

The total installed capacity of Peru's electric system was 2,516 megawatts (MWe) in 1976. The government owns nearly 60 percent of the capacity (principally through ElectroPeru, a state-owned utility) and accounted for 64 percent of electric generation. The rest of the capacity is owned by various industrial, mining, and agricultural enterprises and is classified as "autoproductores". A breakdown of installed capacity is shown in Table 2.3-11. Over three-fourths of the public sector capacity is hydroelectric, while 76 percent of the "autoproductores" capacity is oil-fired.

ElectroPeru currently operates 12 unconnected transmission and distribution grids. Plans for interconnecting these independent systems into three separate grids have been prepared. Appendix B.2 contains a detailed discussion of the electric sector, including an elaboration of the integration plans.

Table 2.3-11

Generating Capacity (MWe), 1976¹³

	<u>Hydroelectric</u>	<u>Thermal</u>			<u>Total</u>
		<u>Steam</u>	<u>Gas Turbines</u>	<u>Diesel</u>	
Public Sector	1,156.0	14.5	143.9	180.6	1,495.0
Autoproductores	<u>249.8</u>	<u>387.5</u>	<u>87.9</u>	<u>295.6</u>	<u>1,020.8</u>
Total	1,405.8	402.0	231.8	476.2	2,515.8

FIGURE 2.3-10 ANNUAL GROWTH RATES IN ELECTRICITY CONSUMPTION, 1964 - 1976¹³

FIG 2.3-11 ELECTRIC ENERGY CONSUMED. 1976¹³

Notes and References to Section 2

1. According to the Peruvian "Census of Population" (1973) definition of urban population. In 1978, Peru's 16 largest cities accounted for 41 percent of the nation's total population.
2. U.S. Department of State, "Background Notes," Washington, D.C., December 1977.
3. Instituto Nacional de Planificacion, "Plan de Mediano Plazo," (Mid-term Plan), Lima, Peru, July 24, 1978.
4. "Plan de Mediano Plazo", op. cit.
5. U.S. Embassy, Lima, "Semi Annual Economic Report," March 1979.
6. Speech by General Alcibiades Saenz Barsallo, Minister of Economy and Finance, Lima, Peru, June 14, 1978.
7. "Plan de Mediano Plazo", op. cit.
8. Banco Central de Reserva del Peru, "Memoria 1976," Lima, Peru, 1976, p. 33.
9. U.S. Geological Survey, "The Energy Resources of Peru," Annex-1 to this report, October, 1978.
10. Paul Willmore and John Steele, "Report on Hydro Power--Peru," Annex-5 to this report, July, 1978.
11. This section is based on a report by E. Boes, Sandia Laboratory, and P. Teagan, Arthur D. Little, Inc., Annex-7 to this report, September 1978.
12. Annex-1, op. cit.
13. Ministerio de Energia y Minas, Direccion General de Electricidad, "Anuario de Estadística Electrica, 1976."

3.0 REFERENCE SUPPLY AND DEMAND PROJECTION

3.1 Approach, Procedures, and Assumptions*

This section describes the future energy supply-demand situation in Peru as it may evolve over the next 22 years, assuming the continuation of current Peruvian government policies and programs. As a result, some potential resources (e.g., coal, wind, biomass, solar, geothermal) are not included or are only included to a minor extent.

The central process in the analysis involves the projection of both the future levels of energy-consuming activities and the efficiencies by which certain fuels are expected to supply those activities. In the iron and steel category, for example, production of iron ore and output of steel are projected for 1985 and 2000, and the technologies to be employed are specified. Thus, the requirements for electricity, fuels for process heat, and coking coal can be determined. Similar activity level projections and fuel requirements are made for other industrial activities, the residential sector (water heating, lighting, and the like), transportation, and agriculture.

Assumptions are then made about the energy conversion technologies used to convert resources into fuels to satisfy projected demands. Of particular importance is the electric sector, in which the installed capacity and operating characteristics of generating plants must be specified. The transport of fuels, the transmission of electricity, and the refining of crude oil to petroleum products are examples of other key energy supply activities.

The "Reference Projection" provides a complete and integrated description of energy demand and supply for 1985 and 2000. For purposes of analysis, it is convenient to represent this projection in the form of a Reference Energy System, as discussed in Section 1.3.3. The reference projection is intended to reflect current plans and policies in the energy area, as well as in industry, transportation, housing, and other important sectors. New energy resources and technologies are not included in the Reference Case, since they represent options that must be evaluated vis-a-vis some common standard. Indeed, the reference case is not to be construed as a prediction of the future. Rather, it is designed to serve as a vehicle for the analysis of options and policies.

The remainder of this section summarizes the construction of the reference projection and presents the Reference Energy Systems that are used for the analysis of energy strategies in Section 4.

* The specific basis for each of the elements of the projections is described in the following sections and in Appendix B.

3.2 Economic Projections

3.2.1 Introduction: Economic projections provide a context within which the energy system can be projected. Energy demand is closely related to economic factors, and the projections presented here illustrate this obvious and important relationship. By taking economic trends and futures into account when estimating energy demands, we ensure the reasonableness and feasibility of the goals that are implied by reference energy projections based on economic activity levels.

Data on sectoral activity levels were sometimes not available to the team during the information gathering phase of the cooperative program. In such instances, economic sectoral growth projections are used as a proxy for activity level data. In those sectors where activity level data were available, economic projections were found to be compatible. These projections were made on the basis of data obtained from the Instituto Nacional de Planificacion (INP, National Institute of Planning), as well as planning offices in various ministries. Despite some differences that are discussed below, the projections presented here are generally in agreement with official Peruvian estimates and plans.

The future is, of course, anchored in the past. Over the six years ending in 1976, and also during the 16 years ending in that same year, the average annual rate of growth of Peru's real gross domestic product (GDP) was 5.9 percent. During the five years prior to 1970, GDP growth averaged 4.7 percent. After peaking at 7.8 percent in 1974, however, growth slackened each year. In 1977, GDP actually fell 1 percent and it now appears that in 1978 it will fall still further, perhaps as much as 3 percent or more. The country's current economic stagnation, and the circumstances that precipitated it, must be taken into consideration in making short-term projections.

Our projections of future economic activity assume that current inadequacies of production and of domestic and overseas demand will be corrected, and that flows of productive investment and efficiency in resource use will eventually be reestablished. If recovery begins in two years, the average growth rate in the 1976-1985 period should be approximately 1.7 percent. Such a growth rate is lower than that assumed by other sources which have not taken the economy's 1978 performance into account.² Despite differences in timing, however, we have assumed a structure of recovery very similar to that projected by the INP. Exports of minerals and refined mineral products play a major role as more mines and facilities currently under construction come on line. Projections of some of the major sectors of the economy are outlined in the subsections below.

For the 1985-2000 period, the average annual growth rate of GDP assumed in this study is 5.0 percent, comparable to the rates projected by the INP in its draft long-term plan.³ Figure 3.2-1 shows historical and projected GDP.

FIGURE 3.2-1 GROSS DOMESTIC PRODUCT (GDP) BY YEAR – REFERENCE CASE

3.2.2 Manufacturing: The manufacturing sector has been particularly hard-hit during the current economic stagnation. Sales of consumer goods have been depressed, largely due to sagging real per capita incomes together with rising production costs. Food processing, including fish-meal production, has dropped due to the combined effects of a temporary government ban on fishing to restore the anchovy crop and stagnating agricultural production. Food processing is projected to remain depressed until the mid-1980s.

Our projections assume that manufacturing as a whole will remain depressed until the anticipated economic recovery in 1980-81. We project a rate of growth of 5 percent per year by 1984, resulting in a nine-year average (1976-85) growth of one percent per year. Growth from 1985 to 2000 is projected to be 5 percent per year, reflecting the general economic recovery from the present economic stagnation.

3.2.3 Construction: Construction was down 10 percent in 1977⁴ and is not expected to do much better in 1978. Therefore, growth rates for the first four years (1976-80) are projected to be negative, averaging -6.0 percent per year. Construction is assumed to pick up with the general economic recovery in 1980-81 and to average 3.8 percent per year growth over the 1980-85 period, bringing the nine-year average (1976-1985) growth to -0.7 percent per year.

3.2.4 Agriculture: Growth in the agricultural sector is projected to be 1.1 percent per year for the 1976-85 period. This is consistent with historical rates, which have run under one percent per year in recent years. However, a number of major irrigation and land reclamation projects are planned. For example, Majes (near Arequipa) is designed to bring 60,000 hectares of previously untitled land into production by 1990. Others are planned in Olmos and in the Marañon River Valley; these, along with other, smaller projects, could add significantly to Peru's arable land area.

The completion of these projects, combined with increased investment, should enable the agricultural sector to sustain a rate of growth of 3.0 percent per annum in the years after 1985. This approximates the population growth rate and is in accord with estimates obtained in interviews with the Peruvian Ministry of Agriculture.

3.2.5 Fishing: The fishing industry has yet to recover fully from the precipitous decline in the anchovy stock in 1972. The current ban on fishing is expected to remain in effect for several more years, as Peru wishes to avoid jeopardizing the recovery of the depleted anchovy stock. Sectoral production will thus lag over the nine-year period 1976-85.

Fishing is projected to grow at a rate of 2.5 percent per year from 1985 to the year 2000. This figure agrees with estimates made by the INP and assumes a gradual increase in fishing as the stock is replenished.

3.2.6 Mining and non-ferrous metals: The mining and non-ferrous metals sector (including mining of iron ore) is projected to grow at a rate of 6.7 percent in the period 1976-1985. This is in accord with INP estimates and reflects the completion of several new mines, concentrators, and smelters during the period. Among these are a zinc refining plant at Cajamarquilla (near Lima) that is designed to produce 100,000 metric tons a year of refined zinc. Also important are continued expansions of facilities at Cuajone and Cobriza, two major copper mining and processing centers. Expansion of capacity for lead, zinc, and copper is projected for the facilities at La Oroya. The average annual growth in the period 1985-2000 is expected to drop to 4 percent because fewer mines and processing facilities will be established during that period.

3.3 Energy Demand Projections

3.3.1 Introduction: This section covers reference energy demand projections for 1985 and the year 2000. Building on the 1976 supply/demand picture that was described in Section 3.2, these projections use economic activity analysis, in which levels of energy-consuming economic activities (e.g., tons of ore mined, number of ton-kilometers of freight moved) are extrapolated based on demographic and economic considerations, and then multiplied by appropriate specific energy requirements.

The reference projection consists of single evaluations of energy demands in each of the reference years (1985 and 2000) with no examination of a high and a low range of energy demand. Such an approach is appropriate to the perturbation analysis (in Section 4.0) that supports the development of strategies and options. However, the approach is not meant to imply an absence of uncertainties in these projections.

Changes in specific assumptions can give rise to substantially different projections. Thus, in the residential and the transportation sectors (where some assumptions are particularly sensitive), alternative projections have been produced that explore the effect of these modified assumptions. These are presented in Appendix B together with the detailed description of the derivation of the reference projections. In the subsections that follow, summaries of the sectoral reference energy projections are given.

3.3.2 Sectoral projections:

3.3.2.1 Residential and commercial: Energy demand in the residential sector is driven by the growth rate in households. A few key assumptions are made. First, it is assumed that rural-to-urban migration continues at its historical rate resulting in a changeover from noncommercial fuels to the kerosene burned by urban poor. Second, it is assumed that the use of kerosene increases in rural areas, replacing firewood and other noncommercial fuels. (As the alternative projection in Appendix B

shows, there is some uncertainty implicit in this assumption.) Lastly, substantial saturation effects are incorporated in urban household electricity consumption. This assumption is based on the income effects of the sustained economic growth rate of 5 percent postulated in Section 3.2.1.

Projections of the number of households from 1985-2000, used in the Reference Case, show a leveling off in rural households (due to rural-to-urban migration) and an increasing share of urban households in urban "shanty towns" (also called "pueblos juvenes" or "young town" complexes). Comparisons with the 1976 situation are shown in Table 3.3-1. Table 3.3-2 presents a summary of the projected 1985 and 2000 energy demands for the residential and commercial sectors, and Table 3.3-3 shows the calculated growth rates for these fuels from 1976-1985 and from 1985 to 2000.

Table 3.3-1

Household Projections, 1985 - 2000

	<u>1976</u>	<u>1985</u>	<u>2000</u>
	(in thousands of units)		
Urban Households	1,220	2,011	4,609
of which in pueblo juvenes	200	425	1,283
Rural Households	2,320	2,885	2,738
Total	3,540	4,896	7,347

Source: See Appendix B

Table 3.3-2
Residential and Commercial Energy Demand
(10¹⁵ Joules)

	1985						2000					
	Residential				Commercial	Total	Residential				Commercial	Total
	Cooking -Heating Urban	Cooking -Heating Rural	Lighting	Other			Cooking -Heating Urban	Cooking -Heating Rural	Lighting	Other		
Electric	1.54	—	1.35	9.11	4.58	16.58	8.10	—	3.18	29.67	11.78	52.73
Kerosene	27.46	8.70	7.62	—	—	43.78	55.53	27.00	9.32	—	—	91.85
LPG ^a	7.70	—	—	—	—	7.70	16.20	—	—	—	—	16.20
Firewood	—	174.00	—	—	—	174.00	—	97.20	—	—	—	97.20
Other	—	23.20	—	—	—	23.20	—	10.80	—	—	—	10.80
Total	36.70	205.90	8.97	9.11	4.58	265.26	79.83	135.00	12.50	29.67	11.78	268.78

^a Liquefied petroleum gas

Source: See Appendix B

Table 3.3-3

Growth Rates, Residential and Commercial Sector Fuels

Fuel	Periods	
	1976-1985	1985-2000
	(in percent)	
Electric	6.5	7.7
Kerosene	5.0	4.4
LPG	4.1	5.1
Firewood	2.6	-3.5
Other	0	-5.2

3.3.2.2 Industry: The energy demand projections for the industrial sector are based on documented capacity expansion plans of all major mining and manufacturing concerns. These are detailed in the report on industrial sector demand⁶ and summarized in Appendix B. Within the present economic climate, not all of these expansion plans will necessarily proceed as envisioned in feasibility studies. Thus, the reference projection escalates industrial energy demand at growth rates for industrial subsectors, except for two export-oriented industries, mining and cement, and for the iron and steel industry, in which added capacity will replace imports. For the latter industries, energy use was projected at levels of full capacity.

The approach chosen here does not take into account new and unforeseen industries that may be established between now and the year 2000. It is generally true that primary industrial activities tend to be more energy-intensive (metals, paper, cement, etc.), and the growth in new industry is mostly in downstream manufacturing activities (electronics) that are not energy-intensive. To account for these new, or "phantom", demands, however, a 1985-2000 growth rate for miscellaneous electric uses of 6 percent was used, compared with a 5 percent growth for the economy as a whole.

Table 3.3-4 summarizes the coal, oil, and electricity projections for 1985 and the year 2000 with 1976 serving as a reference. Table 3.3-5 shows the breakdown used in the reference projection between petroleum products used directly and petroleum products used for the self-generation of electricity within industry (the "autoproduktors").

Table 3.3-4

Summary of Mining and Manufacturing Demand Projections*
(10¹⁵ Joules)

Sectors	1976			1985			2000		
	Coal	Oil	Elec.	Coal	Oil	Elec.	Coal	Oil	Elec.
Mining and non-ferrous	1.6	19.9	7.1	2.8	35.3	13.5	5.1	63.1	24.7
Steel	6.0	1.8	0.7	15.6	4.7	1.9	56.7	17.0	6.8
Cement	—	9.2	0.9	—	15.4	1.7	—	29.0	3.4
Petrochemicals	—	0.2	0.1	—	0.4	0.1	—	0.6	0.1
Chemicals	—	1.5	1.0	—	2.5	1.6	—	4.2	2.7
Fertilizers	—	5.3	0.6	—	7.5	.8	—	15.6	1.7
Fisheries	—	9.0	n.a.	—	7.0	n.a.	—	10.1	n.a.
Glass	—	4.9	n.a.	—	4.9	n.a.	—	10.9	n.a.
Food Processing	—	6.3	n.a.	—	6.9	n.a.	—	11.6	n.a.
Textiles	—	3.1	n.a.	—	3.7	n.a.	—	7.7	n.a.
Paper	—	3.1	n.a.	—	3.4	n.a.	—	7.1	n.a.
Construction	—	1.8	n.a.	—	1.7	n.a.	—	3.8	n.a.
Others	—	20.6	3.9	—	22.5	5.4	—	55.2	12.9
Totals	7.6	86.7	14.3	18.4	115.9	25.0	61.8	235.9	52.3

*The oil demands shown here include the diesel used for self-generation of electricity.

Source: Appendix B

Table 3.3-5

Petroleum Use in Industry

	1976	1985	2000
		(10 ¹⁵)	joules)
Petroleum to Mining Sector	19.9	35.3	63.1
to Electricity ^a	6.8	12.9	23.6
to Direct Uses	13.1	22.4	39.5
Petroleum to Other Industries	66.9	80.6	172.8
to Electricity ^a	11.8	15.6	23.7
to Direct Uses	55.1	65.0	149.1
Total	86.8	115.9	235.9

^a Refers to self-generation of electricity ("autoproductores")

There are demands for fuels other than those shown above; they are discussed briefly here. Non-energy uses of petroleum (asphalts, lubricants, solvents) are obtained as a fixed (about 2 percent) proportion of total crude oil through refineries in the reference years. The use of natural gas for feedstock is obtained from capacity expansion plans for urea production. The use of natural gas as a fuel is projected to decrease by 1985, in line with expected production decreases in the northwest areas, and to be maintained at approximately constant levels thereafter. The use of coal in sectors other than iron and steel and mining is not well identified; the base year of 1976 includes 3.2×10^{15} joules of these unidentified uses (which are probably isolated cottage industries). These uses were escalated at a 5 percent annual growth rate. Energy demand for agriculture is projected from the 1976 base at a rate of 1.0 percent to 1985, and at 3.5 percent per year in 1985-2000. These rates were obtained from the INP. Table 3.3-6 summarizes these energy demands.

3.3.2.3 Transportation: The energy demand projections for the individual transportation modes are determined by projecting transportation activity levels in 1985 and 2000. These are then multiplied by the projected energy intensity of each mode to obtain the respective energy demands. For the reference projections, no change in energy intensity was assumed, and 1976 energy intensities were used. Activity levels were projected based on a set of estimated growth rates that were determined in various ways. (See Table 3.3-7.) The basis for their estimation is detailed in Appendix B. Projected activity levels by transportation mode are summarized in Table 3.3-8.

Table 3.3-6

Energy Demands, Other Uses

Uses	<u>1976</u>	<u>Year</u>	<u>2000</u>
		<u>1985</u>	
	(10 ¹⁵ joules)		
Non-Energy			
Petroleum Products	4.6	6.6	13.2
Natural Gas	1.7	6.1	18.0
Natural Gas (fuel use)	18.0	12.5	11.0
Coal	3.2	5.7	10.3
Agriculture			
Petroleum	8.4	9.2	14.1
Electricity	1.1	1.2	2.0

Source: Appendix B

Table 3.3-7

Estimated Growth Rates of Transportation Activity
Level By Mode Between 1976 and 2000

<u>Mode</u>	<u>Average Annual Growth Rate</u>	
	<u>1976-1985</u>	<u>1985-2000</u>
	(percent)	
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

Source: Appendix B

Total energy demand in the transportation sector is projected to be 156×10^{15} joules in 1985 and 351×10^{15} joules in 2000. This represents an average annual growth rate of 3.7 percent in overall transport energy between 1976 and 1985 and 5.5 percent over the 1985-2000 period. Among the individual modes, trucks will remain the dominant energy user. Trucking will account for over 40 percent of the projected total transport energy demand in 2000. The changes of relative shares of other modes are also small. Table 3.3-9 presents the reference case transportation energy projections to 1985 and 2000.

Table 3.3-8

Transportation Activity Level Projections, 1976-2000

Mode	Activity Unit (10^9)	1985	2000
Automobile	Vehicle-kilometers	4.24	8.81
Motorcycle	Vehicle-kilometers	0.68	1.41
Bus	Passenger-kilometers	27.73	63.98
Truck (freight)	Ton-kilometers	7.65	19.67
Rail (freight)	Ton-kilometers	1.47	2.65
Rail (passenger)	Passenger-kilometers	0.69	1.43
Air	Passenger-kilometers	1.97	3.19
Ship	Ton-kilometers	7.96	19.08

Source: Appendix B

Table 3.3-9

Energy Consumption, Transport Sector, by Mode

Mode	1976	Year 1985 (10^{15} joules)	2000
Truck	44.2	57.7	148.4
Automobile	22.1	28.8	59.9
Air	13.6	19.4	34.9
Ship	13.5	20.1	38.9
Bus	15.0	27.8	63.9
Rail	1.9	2.7	4.9
TOTAL	110.3	156.5	350.9

Source: Appendix B

3.3.2.4 Electric Sector: Future consumption of electricity is obtained by totalling the projected electricity requirements in the residential, commercial and industrial sectors (tabulated in 3.3.2.1 and 3.3.2.2 above). To determine the consumption requirements to be met by the public utilities it is necessary to segregate the portion of total electricity demand that will be met by industrial self-generation (autoproduktors). Table 3.3-10 presents this breakdown, and shows that 2300 gigawatt hours in 1985, and 3675 gigawatt hours in 2000, are assumed to be met by the autoproduktors. After accounting for transmission and distribution losses of 12 percent, total electric generation required from the public utilities is 10,960 gigawatt hours in 1985, and 29,632 gigawatt hours in 2000.

Table 3.3-10

Reference Projection Electric Energy Consumption^a
(in GWh)

Sector	1985	2000
Residential and Commercial	4,611	14,667
Industry, Total	6,917	14,528
Industry, Self-Generated	<u>-2,300</u>	<u>-3,675</u>
Industry, Public Utilities	4,617	10,853
Agriculture	417	556
Losses (12 percent)	<u>1,315</u>	<u>3,556</u>
Total Generation Requirements	10,960	29,632

^a Source: Tables 3.3-2 and 3.3-4

Since Peruvian plans do not call for a completely integrated national system in the foreseeable future, the expansion of public utility facilities must be assessed separately for each of the three planned major subsystems (the two isolated units in the jungle region are too small to warrant individual assessment). For this purpose, peak demand projections developed by representatives of the Ministry of Energy and Mines have been used as guidelines (Table 3.3-11). The peak loads of 2606 megawatts in 1985 and 6746 megawatts in 2000, are consistent with the projected requirements of 10,960 (1985) and 29,632 (2000) gigawatt hours, assuming a constant load factor of 0.50 for the system as a whole. The details of the demand projections are given with the capacity expansion plans in section 3.4.4.

Table 3.3-11

1985-2000 Demand Projection (MWe)

Year	System			
	Centro Norte	Sur Oeste	Sur Este	Total
1985	2230	295	81	2606
2000	5810	750	186	6746

Source: Ministry of Energy and Mines.

Annex 5, pp. 38-39, cites an earlier Ministry of Energy and Mines document that includes slightly different projections.

3.4 Energy Supply Projections

3.4.1 Future oil production: Estimates of oil production in Peru for the years 1978-1985 are shown in Table 3.4-12. These estimates were generated by USGS specialists through discussions with officials of the Ministry of Energy and Mines and with officials and scientists of Petro-Peru, Occidental, and Belco. The basic assumption in making these estimates was that the rate of oil production, at least through 1985, would not be affected by significant new discoveries. That is, exploration for new oil deposits has all but ceased in most areas of Peru, and a renewal of exploratory ventures probably would not be reflected in production increases until after the middle 1980's because of the time lag between exploration and production phases.

As shown in Table 3.4-12, oil production in Peru through 1985 can be placed in 5 categories: (1) Amazon region (operated by Occidental); (2) Amazon region (operated by PetroPeru); (3) primary recovery from the Talara onshore area; (4) secondary recovery from the Talara onshore area; and (5) the Talara offshore area (operated by Belco). Each is discussed separately in the following paragraphs.

3.4.1.1 Amazon region (Occidental): Occidental Petroleum Corporation now operates eight fields in Block 1A, located in northern Peru near the Ecuadorian border. Five of these fields are producing oil, one field (Carmen) produces only small amounts of gas, and the remaining two (Huayuri and Tambo) are not yet in production. Occidental's first discovery in this area was in 1972. Full production was delayed because of insufficient transportation facilities. In early 1978, a spur oil pipeline with a capacity of 80,000 bbl/day was completed. This spur line extends from the main Trans-Andean pipeline to Occidental's gathering station on Andoas.

Table 3.4-12

Estimates of Future Yearly and Daily Production of Oil
in Peru for the Years 1978-1985

Year	*Amazon region Oxy	*Amazon region Oxy new fields	*Amazon region pp	*Talara onshore primary recovery	*Talara onshore, secondary recovery Oxy	*La Brea- Parinas secondary recovery	*Talara offshore Belco	Total (Million barrels per year)	Total (Thousand barrels per day)
**1978	25.5	-	10.0	12.0	0.6	-	11.0	59.1	162
1979	40.0	-	10.7	11.4	3.0	-	10.8	75.9	208
1980	40.0	-	10.7	10.8	9.8	-	10.6	81.9	224
1981	35.3	-	10.0	10.3	12.0	-	10.4	78.0	214
1982	29.0	-	9.2	9.8	12.0	-	10.2	70.2	192
1983	26.0	1.8	8.6	9.3	12.0	3.0	9.9	70.6	193
1984	21.5	3.6	7.5	8.8	11.4	9.8	9.5	72.1	198
1985	17.0	3.6	6.3	8.4	10.0	12.0	9.2	66.5	182

* Yearly production rates in millions of bbl/yr

** 1978 production rates refer to last quarter of year

Source: USGS, Annex 1

Note: For comparison purposes, projected production figures provided to the USGS by the Ministry of Energy and Mines, in thousands of bbl/day, were as follows: 214 (1979), 213 (1980), 207 (1981), 210 (1982), 202 (1983), 186 (1984), and 163 (1985).

According to a spokesman for Occidental, the company is installing new pumps on the spur line to raise delivery capacity to 120,000 bbl/day. In addition to this delivery capacity, Occidental's new river terminal on Rio Tigre, east of Shiviyaçu, has made it possible to barge over 15,000 bbl/day to the main pipeline station at Saramuro.

Total oil production from Block 1A on May 10, 1978, was 72,000 bbl. This production was from five fields as follows:

Forestal	6,000 bbl
Northeast Shiviyaçu	400 bbl
Shiviyaçu	11,000 bbl
South Capahuari	49,000 bbl
North Capahuari	<u>5,600 bbl</u>
Total	72,000 bbl

Officials of Occidental indicate that oil production could reach 110-120,000 bbl/day in the latter part of 1978. The increase in production is expected chiefly from South Capahuari. By the use of added gas lift and the drilling of two more wells, its production could reach 70,000-75,000 bbl/day. In the latter part of 1978, plans are to put Huayuri field on-line with a production capability of perhaps 20,000-25,000 bbl/day. According to officials of Occidental, additional production in 1979, of about 1,000 bbl/day, could come from Block 1B. Occidental recently acquired this block which was previously operated and later abandoned by Union Oil Company after the discovery of heavy oil (17° API). Occidental plans to produce some of this heavy oil by mixing with lighter oil from Block 1A. Other production in 1979 could come from Tambo or the yet untested Torisa field. It is estimated that small new discoveries, perhaps of light oil in 1B, will increase production by 5,000-10,000 bbl/day in the 1982-1983 period (Table 3.4-12). Without other significant discoveries, we estimate that Occidental's production will peak at 110,500 bbl/day in the 1979-1980 period and then slowly decline.

3.4.1.2 Amazon region (PetroPeru): In 1976, PetroPeru drilled 79 development wells in Block 8. Sixty-two of these wells gave positive results, and oil production from PetroPeru's four production areas in Block 8 was 56,000 bbl/day by mid-1977. By June of 1978, however, average daily production had declined to about 27,800 bbls as follows:

Corrientes	25,000 bbl
Pavayacu	2,600 bbl
Yanayacu	200 bbl
Capirona	<u>small amounts</u>
Total	27,800 bbl

The increase in production from Capirona is expected as a result of new drilling.

During the years 1978-1985, additional PetroPeru oil production of about 1,000-1,500 bbl/day will probably come from the company's two producing fields in the Ucayali basin. Total cumulative production from 1939 to mid-1977 from the Agua Caliente and Maquia fields in the Ucayali basin has been 21 million barrels. Total average daily production from these two fields was about 1,300 bbl during the first six months of 1977.

On the basis of current estimates, we expect PetroPeru's Amazon production to be about 29,400 bbl in the 1979-1980 period, followed by a rapid decline (Table 3.4-12).

3.4.1.3 Talara onshore (primary recovery): The first commercial well was drilled in 1863, making this region the cradle of the South American oil industry. As of mid-1977, cumulative production was 839 million bbl. Daily production of about 33,000 bbl comes from some 2,100 wells. Maximum oil production from a well in this area is about 800 bbl/day, but most are making 4-5 bbl/day (Gordon, 1977). Output of oil in the year 1966 was 20.2 million bbl, in 1975 about 13.9 million bbl, and in 1976 about 12.9 million bbl. Over the 10 year period 1966-1976, the average yearly decrease in oil production was 3.6 percent, whereas, between 1975 and 1976, the decrease rose to almost 7 percent. Based on these statistics, it is estimated that between 1978 and 1985 the average yearly decline in oil production from primary recovery in the Talara onshore area will be about 5 percent (Table 3.4-12).

3.4.1.4 Talara onshore (secondary recovery): For purposes of secondary recovery operations, the Talara area has been divided into two sections: Lobitos-El Alto-Los Organos and La Brea-Parinas. Occidental Peruvana, Inc. and its joint venture partner, Bidas Exploraciones y Produccion S.A., were selected to conduct secondary operations in the first Talara section. According to information received from officials of Occidental and the Ministry of Energy and Mines, secondary operations are expected to begin in the 1978-79 period, and peak oil production, of perhaps 33,000 bbl/day, will be reached in about 1982 (Table 3.4-12).

Secondary recovery operations are expected to begin in the La Brea-Parinas section in the 1980-81 period, and it is estimated that peak production will be reached in about 1985. It is estimated that peak production from these operations will be about 33,000 bbl/day (Table 3.4-12).

3.4.1.5 Talara offshore: Belco Petroleum, the only operator in this area, is developing its Zocalo II area on the continental shelf offshore of Talara. Discovery of offshore fields was largely an extension of on-shore work. In the years 1971-77, Belco made 15 discoveries and by mid-1977 was producing oil at the rate of 28,600 bbl/day. By the end of 1976, Belco had drilled a total of 435 wells in the Continental Shelf between Sechura and Zorritos. Of these wells, 285 are now producing, 110

are closed, and 40 have been abandoned. As in the onshore area, production from individual wells is small. It is estimated that yearly oil production rates for the off-shore Talara area will remain relatively constant during the years 1978-1985, with only a small decline of perhaps 1-3 percent (Table 3.4-12).

Currently producing Peruvian oilfields will be depleted, or nearly depleted, by the year 2000. If we assume that no new additions (beyond those shown in Table 3.4-12) are made to Peru's measured oil reserves, the authors calculate that Peru's total oil production will range from 10 to 15 million bbl per year at the turn of the century. However, it is unlikely that this situation will occur. It seems more likely that exploration in the Amazon basins will become more attractive as future world oil demands and oil prices increase. If we assume that one-half of Peru's undiscovered oil resources are moved into the measured reserve categories during the 1990's (a reasonable assumption, we believe), it is possible that the production rate in the year 2000 could reach 116 million bbl/yr. (In making this estimate, we have used a ratio of 10:1 for yearly production rates versus measured reserves.)

Realization of this production rate by the turn of the century will require an active and continuing exploration program to be initiated in Peru before about 1985. To date, producing fields in Peru have proved to be associated with relatively small structures, and the few tests made several years ago in the Amazon basins suggest that future production will not come from giant fields. The search for small traps will require active exploratory ventures.

3.4.2 Future gas production: Gas production in 1977 amounted to approximately 73 billion cubic feet. It is estimated that during the years 1978 through 1985, gas production in Peru will remain at this level.

Water flooding in the Talara area will increase the reservoir pressure, causing some of the gas to dissolve in the oil, thereby increasing oil production but decreasing gas production. We can expect gas production in the area under secondary recovery to decline somewhat after flooding gets under way. We assume that gas produced in the Talara area will continue to be used primarily for the production of fertilizer.

Estimating future gas production based on past performance is difficult for several reasons. When many old oil fields were in operation there was no market for associated gas, and the gas was flared with no records maintained of the amounts of gas produced. In other situations, gas is re-injected into the formation to maintain reservoir pressure. At some later date this same gas may again be produced and measured; the same gas could conceivably be measured three or four times.

This makes gas production statistics uncertain and estimating future production, based on past performance, a difficult task. It seems probable that more drilling will be done in the Aguaytia gas field, but production of the Aguaytia reserves is not expected before 1985.

As described in Section 2.3, gas resources are estimated to range between 1.3 and 11.5 trillion cubic feet. The range of production of gas in 2000, corresponding to those figures, is 6 to 55 billion cubic feet per year.

3.4.3 Future coal production: Section 2.3 presents an appraisal of the coal resources of Peru. From the discussion there, it is clear that considerable uncertainty exists, not only about the extent of the resources, but, more particularly, about the technical and economic feasibility of extraction of the coal. As a result, further exploration and development studies of the major coal deposits, especially Alto Chicama, Oyon, Jatunhuasi and the Santa Valley, are necessary to obtain a firm idea of their potential for contribution to the Reference Case scenario.

From the demand side, we can project the requirements for the major coal consuming sectors in the Reference Case projection for the year 2000:

- o The Alto Chicama mine-mouth electric power plant. This plant, consisting of two (or possibly three) units aggregating 480 MWe, will consume approximately a million to a million and a quarter tons of coal annually at a plant capacity factor of 60 percent.
- o Expanded iron and steel production at Chimbote will require approximately two to two and a half million tons of coking coal annually by the year 2000. Taking into account the quality of Peruvian coal from the Oyon deposit (the most likely source of supply), it is estimated that at best half of this amount could be supplied domestically.
- o Other sectors, principally lead smelting operations at Centromin as well as other non-ferrous metals mining and refining operations, would require about an additional half million tons.

In sum, the total domestic supply required is in the range of 2.5 to 3 million tons annually by the year 2000. Current indications are that if further exploration and development work proves successful, and if mining techniques appropriate to each of the major deposits are adopted, domestic sources could fulfill the projected requirements.

3.4.4 Electricity supply: In developing generation capacity requirements, Peruvian planners have considered maximum demand projections and have provided for reserves in either of two ways: (a) additional 10 percent or (b) an amount equal to the capacity of the largest unit. Power lost in

transmission and the requirement for diversity in demand are assumed to cancel each other. Projection selection for capacity expansion is founded on some fundamental objectives:

- o Assure the timely provision of reliable electricity that can meet demand at least cost;
- o Increase the use of the nation's hydroelectric and coal potential;
- o Reduce the use of petroleum and petroleum products to the greatest possible extent; and
- o Extend interconnected electric systems.

The capacity expansion plan elaborated below is generally in accordance with these principles, with the exception that a specific allowance is made for system losses. Table 3.4-13 summarizes planned capacity expansion for the Centro Norte subsystem over the period 1978-2000. Similar data are provided for Sur Oeste and Sur Este in Tables 3.4-14 and 3.4-15, respectively. Information on specific facilities is obtained from Reference 8. Generating capacity requirements were derived on the assumption that 10 percent of peak load provides adequate reserve capacity and that transmission and distribution losses amount to 12 percent.

In Centro Norte no oil-fueled generating capacity additions are planned after 1983. In the period 1978-83, 35 MWe of oil capacity additions are planned. Aside from a single 27 MWe bagasse-fired addition planned for 1985, a 50 MWe heat recovery unit in 1988, and a 480 MWe coal-fired capacity planned for 1991-92 operation, all capacity additions are hydro. It is noteworthy that of some 4,343 MWe of planned hydro additions in this subsystem, all but 1,200 MWe are available from the development of identified sites. The bagasse-fired unit is planned for installation at a paper mill where this agricultural residue is also used as feedstock. The heat recovery unit is planned for installation at the Trujillo-Chimbote steel making facility. Three 160 MWe coal-fired units are planned for installation in the Alto Chicama coal fields, where reserves adequate for the life of the plant are believed to exist.

Sur Oeste is the second largest integrated subsystem, with a planned total capacity in the year 2000 of some 875 MWe, as compared to Centro Norte's 6,513 MWe. Its formation is based on the planned integration of the Southern Peru Copper Company (SPCC) and Arequipa systems. Capacity additions planned for the period 1978-2000 are entirely hydro, with the exception of a 66 MWe oil-fired steam unit that will be installed to replace a similar unit that is planned for retirement in 1980.

Sur Este, with a planned capacity of 206.5 MWe in the year 2000, is the smallest of the integrated subsystems. Its capacity growth is based on the expansion of existing hydro electric and thermal facilities at Machu

Table 3.4-13

Capacity Expansion Plan for Centro Norte

Year	Plant/Project	Capacity Expansion (MWe)	Aggregate Cap. (MWe)	Demand Forecast (MWe)	Reserve (Percent)
1978	Piura 1 (T)	5			
	Chiclayo 1 (T)	10	1591	1420	12
1979	Piura 2 (T)	5			
	Mantaro IV, V (H)	228	1824	1515	20
1980	Chiclayo 2 (T)	5			
	Mantaro VI, VII (H)	228	2057	1620	27
1981	Expansion, Canon del Pato (H)	50			
	Piura 3 (T)	5	2112	1725	22
1982	No Additions	—	2112	1840	15
1983	Restitucion (H)	217			
	Chiclayo 3 (T)	5	2334	1960	19
1984	No Additions	—	2334	2090	12
1985	Carhaquero (H)	75			
	Pulpa Blanqueada (T)	27			
	Chira-Piura (H)	24	2460	2230	10
1986	Sheque I-II (H)	300	2760	2380	16
1987	Sheque III (H)	150	2910	2535	15
1988	Olmos I (H)	150		2885	15
	Chimbote Heat Recovery (T)	50	3110		
1989	Olmos II (H)	210	3320	2885	15
1990	Sheque IV (H)	150			
	Yuncan (H)	126	3596	3095	16
1991	Alto Chicama I (T)*	160	3756	3300	14
1992	Alto Chicama II (T)*	160	3916		
	Chicama III (T)*	160	4076	3510	16
1993	El Chorro (H)	150	4226	3740	13
1994	Carapongonga (H)	300	4526	3980	14
1995	Churin Huaura (H)	111			
	Santa C-2 (H)	65			
	Fortaleza I (H)	210	4912	4240	16
1996	Fortaleza I (H)	173	5085	4520	13
1997	Quiutan-Huara (H)	228			
	Hydro A (H)	150	5463	4810	14
1998	Hydro B&C (H)	300	5763	5125	12
1999	Hydro D&E (H)	300	6063	5455	11
2000	Hydro F&G&H (H)	450	6513	5810	12

H = Hydro

T = Thermal

* Coal fired

Table 3.4-14

Capacity Expansion Plan for Sur Oeste					
Year	Plant/Project	Capacity Expansion (MWe)	Aggregate Cap. (MWe)	Demand Forecast (MWe)	Reserve (Percent)
1978	Existing		296.8	200	48
1979	Arequipa I (T)	16.5		210	53
	Chilina III (T)	9.0	322.3		
1980	No Additions		322.3	225	43
1981	No Additions		322.3	240	34
1982	No Additions		322.3	250	29
1983	No Additions		322.3	265	22
1984	No Additions		322.3	280	15
1985	Charcani V (H)	135			
	Retire Charcani I,II,III(H)	6.8	450.5	295	53
1986	No Additions		450.5	330	36
1987	No Additions		450.5	350	29
1988	No Additions		450.5	370	22
1989	No Additions		450.5	395	14
1990	Lluta 1 (H)	137	587.5	420	40
1991	No Additions		587.5	440	33
1992	No Additions		587.5	470	25
1993	No Additions		587.5	500	17
1994	No Additions		587.5	530	11
1995	Lluta 2 (H)	137	724.5	560	29
1996	No Additions		724.5	595	22
1997	No Additions		724.5	630	15
1998	Hydro <u>O</u> (H)	150	874.5	670	30
1999	No Additions		874.5	710	23
2000	No Additions		874.5	750	17

Table 3.4-15

Capacity Expansion Plan for Sur Este

Year	Plant/Project	Capacity Expansion (MWe)	Aggregate Cap. (MWe)	Demand Forecast (MWe)	Reserve (Percent)
1979	Dolores Patas (T)	7.5	55.6	41	36
1980	No Additions			43	29
1981	No Additions			44	26
1982	No Additions			46	21
1983	Machu Picchu Expansion (H)	69.9	125.5	59	113
1984	No Additions			70	79
1985	No Additions			81	55
1986	No Additions (H)			84	49
1987	No Additions			89	41
1988	No Additions			92	36
1989	No Additions			97	29
1990	Qushuarani Expansion (H)	46	171.5	112	53
1991				116	48
1992				125	37
1993				132	30
1994				140	23
1995				146	17
1996	Hydro Z Expansion (H)s	35	206.5	153	35
1997				161	28
1998				169	22
1999				177	17
2000			206.5	186	11

Table 3.4-16

Electricity Capacity Expansion Summary

Subsystem	Existing: 78 (MWe)		Additions: 78-85 (MWe)		Retirements: 75-85 (MWe)		Additions: 85-2000 (MWe)		System Total: 2000
	Hydro	Fossil	Hydro	Fossil	Hydro	Fossil	Hydro	Fossil	
Centro-Notre	1256.0	320.0	822.0	62.0 ^a			3523	530 ^b	6513.0
Sur-Oeste	65.5	231.3	135.0	91.5	-6.8	-66	424		874.5
Sur-Este	40.0	8.1	69.9	7.5			81		206.5
Iquitos		16.5		25				30	71.5
Pucallpa		6.8		32.5				20	59.3
Total	1361.5	582.7	1026.9	218.5	-6.8	-66	4028	580	7724.8

a) Includes Pulpa Blanqueada, 27 MW, bagasse-fueled

b) Includes Alto Chicama, 480 MWe coal fired, Heat Recovery, 50 MW

Picchu and Dolores Pata, respectively. In addition, the development of 46 MWe at a new hydro site is planned in 1990. In order to meet continued estimated growth in the mid-1990s, an additional 35 MWe will be required. This is shown in Table 3.4-15 as an unidentified hydro site.

The summary Table 3.4-16 notes the additions to the small, isolated Iquitos and Pucallpa systems. These are planned as oil-fired units. Because of their relatively small size, no detailed capacity expansion plan has been included for them in this report. Figure 3.4-2 shows the location of major generation plants planned for 1978-2000.

The Instituto Peruano de Energia Nuclear (Peruvian Nuclear Energy Institute, IPEN) has undertaken a nuclear science and energy program. For the most part, initial activities will cover medical, industrial, and agricultural applications of radioisotopes. The Government of Peru has also recently authorized the establishment of a nuclear research center, at which IPEN plans to install a 10 MW pool-type research reactor and to establish a fuel fabrication capability. IPEN intends to use the center as one means to support uranium exploration activities and to foster the development of the infrastructure necessary to support a nuclear power plant program over the longer term. Before 1995, the point at which construction would start, IPEN plans to reach a decision on building Peru's first nuclear power plant. That decision will depend on the relative practicality and economic advantage of nuclear energy versus hydroelectricity (also see Note 9).

3.5 Supply/Demand Integration

3.5.1 Reference energy systems: Energy demand projections derived above are presented in this section in a Reference Energy System framework. Energy flows to demand categories in the Reference Energy System are obtained from household, industry, and transportation demand projections tabulated in Section 3.3.2. In constructing the Reference Energy System, the technical efficiencies of all of the processes considered are specified. An exception to this rule is made for hydroelectric power; following the convention used by the United Nations and other international agencies, an efficiency of 0.30 is used for hydro power to reflect the amount of fossil energy that would have to be consumed to generate the same amount of electricity (rather than the actual efficiency of hydro turbines and generators, which is approximately 80 percent). The electricity consumption totals for 1985 and 2000 are then balanced against the capacity expansion and retirement plans for hydroelectric and thermal plants in the public utility sector.

The Reference Energy System for 1976, presented in Figure 3.5-3, provides historical energy flows. The reference projection cases for 1985 and the year 2000 that are presented in Figures 3.5-4 and 3.5-5 show only total crude oil and coal demand and do not display the fractions that are domestic and that are imported; Section 3.4 provides projections of imported versus domestic oil and coal.

LOCATION OF MAJOR GENERATION PLANTS, 1978-2000

FIG 3.4-2

3.5.2 Summary of reference case: Total resource consumption by fuel for 1976, 1985 and 2000 is shown in Figure 3.5-6. The projected demands for commercial energy in 1985 and the year 2000 are summarized in Figures 3.5-7 and 3.5-8. Table 3.5-17 depicts the resulting sectoral growth rates for the 1976-1985 and 1985-2000 periods. It can be seen that energy to the industrial sector grows at only 3.6 percent per year to 1985, in accordance with the low growth rate of the economy that was assumed over that interval. The industrial consumption growth rate increases to 5.5 percent per year, thereafter. The residential and commercial sectors grow much more quickly, at 5.2 percent and 5.9 percent for the two periods, respectively. This occurs in spite of the economic slowdown in the first period, and reflects the large increase in urban households through rural-to-urban migration. This trend involves a changeover from firewood and other noncommercial fuels to kerosene and other commercial fuels and also affects urban public transportation needs. Transportation growth is linked to economic output projections for freight operations, as well, and reflects PetroPeru's ten-year sales projections of special transportation fuels. This sector's energy demand grows at 3.3 and 5.6 percent in 1976-1985 and 1985-2000, respectively.

Figure 3.5-9 displays share of energy demand by sector for 1976, 1985, and 2000. The industrial sector's share of total energy drops slowly from the 1976 level of 37.3 percent to a level of 35.8 percent in the year 2000, while the share of the residential sector goes up slightly and transportation declines slightly after an initial rise.

Total resource consumption, which is the standard international measurement of energy used by organizations such as the United Nations and the International Energy Agency is shown at the left of the Reference Energy System. Total resource consumption for 1985 is 741.3×10^{15} joules, and for the year 2000, $1,318.1 \times 10^{15}$ joules (including noncommercial fuels). The standard measurement excludes noncommercial fuels; the totals with these subtracted are 532.6 and $1,198.6 \times 10^{15}$ joules for 1985 and 2000, respectively, yielding an annual growth rate of 4.2 percent for 1976-1985, and of 5.6 percent for 1985-2000. Tables 3.5-18 and 3.5-19 summarize these energy totals and growth rates.

The latter growth rates are critical in deriving elasticities of energy demand with respect to income (GDP). The elasticity, which is calculated by dividing the projected growth rate of energy by the assumed growth rate of GDP, is rather high for the period 1976-1985--in excess of 2. This result can be explained by several factors. First, and most important, although average GDP growth rates for 1976-1985 are very low (1.7 percent per annum), the growth that does occur is concentrated in the mining, non-ferrous metals, and iron and steel sectors. These industries are highly energy-intensive, and their rapid growth over the period (mining and non-ferrous metals is expected to grow at 6.7 percent per annum) pulls up the elasticity figures.

FIG 3.5-3 REFERENCE ENERGY SYSTEM FOR PERU, 1976

FIG 3.5-4

REFERENCE ENERGY SYSTEM FOR PERU. 1985

FIG 3.5-5 REFERENCE ENERGY SYSTEM FOR PERU, 2000

FIGURE 3.5-6 REFERENCE CASE – TOTAL RESOURCE CONSUMPTION BY FUEL. 1976, 1985, AND 2000

FIG 3.5-7 COMMERCIAL ENERGY DEMAND. 1985

FIG 3.5-8 COMMERCIAL ENERGY DEMAND. 2000

Table 3.5-17

Total and Sectoral Commercial Energy Demand Growth Rate

1976 - 2000 (10^{15} Joules)

Sector	Average Annual Growth Rate		
	1976-1985	1985-2000	1976-2000
Residential-Commercial	5.2	5.9	5.6
Industrial	3.6	5.5	4.8
Transportation	3.3	5.6	4.7
Agriculture	1.0	3.0	2.2
Total	4.1	5.4	4.9

* CALCULATED BASED ON FUEL INPUT LESS ELECTRICITY SUPPLIED TO END-USE ACTIVITIES

FIG 3.5-9 DISTRIBUTION OF COMMERCIAL ENERGY DEMAND BY SECTOR. 1976, 1985, AND 2000

Table 3.5-18
Total Resource Consumption (10^{15} joules)

Energy Type	1976	Year	2000
		1985	
Commercial	367.1	532.6	1198.6
Noncommercial	170.7	208.7	119.5
Total Resource Consumption	537.8	741.3	1318.1

Table 3.5-19
Total Resource Consumption

	Annual Growth Rate		
	1976-1985	1985-2000	1976-2000
Commercial Energy	4.2	5.6	5.0
Noncommercial Energy	2.3	-3.6	-1.5
Total Resource Consumption	3.6	3.9	3.8

Secondly, growth rates for residential and commercial end-uses are quite high due to rural-urban migration, which causes a switch from non-commercial fuels (which are excluded by definition from the standard quantity being discussed) to kerosene. Urban centers, particularly Lima-Callao, account for a disproportionate share of energy consumed relative to population distribution. This higher energy consumption per capita in urban areas also exaggerates elasticities as more of the population moves into cities. That is, since the calculation of residential-commercial energy use was made on the basis of household formation rather than total disposable income in that sector, the fact that household formation is high in urban areas at a time of low GDP growth tends to bias elasticity estimates upwards.

The income elasticity of demand for energy drops to 1.12 during the 1985-2000 period. One reason for this is decreased growth in energy-intensive industries (mining and non-ferrous metals drops from 6.7 to 4.0). Although they are not explicitly incorporated into the projections, increases in oil prices that are likely to occur during the period 1985-2000 would also tend to hold growth in energy consumption down.

Figure 3.5-10 shows the distribution of the energy resources used in 1976 and the distributions corresponding to the 1985 and 2000 reference projections. Figure 3.5-11 shows the projected demand for petroleum products. The importance of petroleum products does not diminish in 1985 and decreases to 65 percent by 2000. The increase in hydroelectricity from a 18.9 percent to a 24.8 percent share (measured as fossil fuel equivalent), and the decrease in the share of oil represent what is perhaps the most important trend in the Peruvian energy system between 1976 and 2000. Development of abundant hydro potential to substitute for increasingly expensive oil is a process that will be more clearly seen in the years after 2000, but a movement in that direction (a decrease in the share of petroleum) breaks the historical trend. Acceleration of this trend by government policy could have significant foreign exchange effects, either by reducing imports or (given sufficient domestic production) by allowing the expansion of exports.

Another view of the impact of the increased share of hydro power is shown in Table 3.5-20, which presents electricity as a percentage of total consumption at end-use, *i.e.*, energy use by the final consumer. This electricity share, which increased from 5.6 percent in 1976 to 10.7 percent in 2000, is sometimes interpreted as a measure of industrialization and standard of living. Figure 3.5-12, which presents the Peruvian case in comparison with other developing countries, shows the relationship of electricity to total energy consumption as a function of GDP per capita.

The reference projection also calls for increased demand for coal. This results from specific projects that were described above as part of the industrial and electric sector projections. Should domestic coal reserves prove adequate, coal consumption could assume a more important role. For a more detailed discussion of coal utilization possibilities, see Section 3.4.

1976 TOTAL 367 (10^{15} JOULES)

1985 TOTAL 533 (10^{15} JOULES)

2000 TOTAL 1199 (10^{15} JOULES)

*MEASURED AS FOSSIL FUEL EQUIVALENT

FIGURE 3.5-10 DISTRIBUTION OF COMMERCIAL ENERGY CONSUMPTION BY RESOURCE. 1976, 1985, AND 2000

FIG 3.5-11 PROJECTED DEMAND FOR PETROLEUM PRODUCTS ($\times 10^{15}$ JOULES)*

Table 3.5-20
Trends in Electrification

Relationship of Electricity Use	Year		
	1976	1985 (in percent)	2000
To total energy at end use	5.6	7.1	10.7
To total commercial energy at end use	8.9	10.9	12.2

3.5.3 Capital and Labor Requirements:¹⁰ This section summarizes the estimates of the levels of capital and labor that will be required to develop the energy sector in Peru. These are based on analyses performed on the Energy Supply Planning Model (ESPM), which the Bechtel Corporation developed for the U.S. Department of Energy. The ESPM estimates draw on assumptions about labor grades and types, characteristics of typical or representative facilities, and estimates about the levels of supply for each energy form, e.g., oil, electricity, etc. (A selection of these parameters for Peruvian facilities is presented in Table 3.5-21; the details for these summary estimates are provided in Annex-10, which was prepared by the Bechtel Corporation.)

In the period between 1968 and 1976, investment in the energy sector¹¹ represented 2.8 percent of GDP and 42 percent of total public investment. Moreover, it seems clear that meeting Peru's future energy requirements will be as much a question of capital availability as one of basic resources. When the energy configuration in the Reference Case is used as the basis for the computation, the cumulative capital requirements for Peru's energy sector are projected to be \$13,978 million (January 1978) for the 1977-2000 period. As shown in Figure 3.5-13, capital requirements for the electric sector, which includes electric power generation, transmission, and distribution, comprise over 60 percent of total investment needs. Based on the estimated production of 318,000 barrels per day that is postulated in the Reference Case, the petroleum sector, which includes exploration, production, refining, and transportation, accounts for 38 percent of total capital requirements. Within the electrical sector, nearly two-thirds of the capital is required for the construction of hydro plants, with 16 percent for transmission and distribution systems and 10.8 percent for diesel and combustion turbine generation in the industrial sector "autoproduktors" (Figure 3.5-13). The balance supports the construction of coal steam electric plants and mini-hydro projects.

FIG 3.5-12 RELATIONSHIP OF ELECTRICITY TO TOTAL ENERGY CONSUMPTION AS A FUNCTION OF GNP PER CAPITA

FIG 3.5-13 PROJECTED SHARE OF CUMULATIVE CAPITAL REQUIREMENTS BY ENERGY SECTOR (1978-2000)

Capital cost requirements for design, construction, and "start-up" of the necessary energy facilities in the Reference Case were estimated on a year-by-year basis, through the year 2000. Table 3.5-22 presents these estimates for selected years. These yearly estimates were accumulated for the entire interval 1978-2000, and the capital requirements were then broken down by facility groups (i.e., those in the oil sector, those in the electricity generation sector). The share of estimated total capital that would be expended domestically, and the share that would support imports, were also estimated and are presented in Table 3.5-23. It shows that the domestic portion of total capital expenditures over the 1978-2000 period is 33.3 percent, the domestic portion in electrical generation facilities is 35.1 percent, and the domestic share in the oil sector is 30.5 percent.

The most important components of total capital requirements are the manpower, materials, and equipment costs. These costs in the year 2000, the average yearly costs over the period 1978-2000, and the total cumulative cost in the same period are displayed in Table 3.5-24. This table also shows the portion of manpower, equipment and material costs that is of domestic origin.

Operation and maintenance costs for the year 2000 and the average yearly costs over the period 1978-2000 are shown in Table 3.5-25.

Table 3.5-21

Input Parameters for Typical Energy Facilities in Peru

Facility	Oil Production			
	Production per Well bbl/day	No. of Producing Wells Per Facility	Depth per Well (m)	Lifetime (years)
On-Shore Oil Recovery, Coastal	300	15	1766	20
On-Shore Oil Recovery, Secondary	300	39	1450	20
On-Shore Oil Recovery, Jungle	3000	15	3850	20
Off-Shore Oil Recovery	525	15	1765	20

Electric Generation		
	Size (MWe)	Lifetime (years)
Coal Steam	160	30
Waste Heat	50	30
Gas Turbine	15	30
Diesel	15	30
Bagasse	10	30
Conventional Hydro 1	25	30
Conventional Hydro 2	150	30
Mini hydro	0.15	30
Geothermal 1	50	30
Geothermal 2	10	30

Electric Transmission		
Capacity	Load	Distance
60 KVAC	30 MW	100 Km
138 KVAC	100 MW	175 Km
220 KVAC	250 MW	250 Km

Table 3.5-22

Yearly Capital Costs for Design, Construction and Start-up, Reference Case (Millions of January 1978 Dollars)					
Facility Group	1980	1985	Year 1990	1995	2000
Oil (Total)	246	223	192	220	327
Gas (Total)	0	0	2	6	8
Coal (Total)	0	0	7	9	15
Conventional Hydro	146	218	146	410	421
Mini-hydro	4	4	4	6	6
Combustion Turbine	6	17	11	6	6
Diesel	26	56	38	21	4
Coal-fired	0	0	117	0	0
Total Generation	183	315	316	450	436
Transmission	53	22	24	43	47
Distribution	14	23	27	33	37
Electricity (Total)	249	358	368	526	520
Total Energy Industry	497	581	568	759	871

Source: Annex - 10

Table 3.5-23

Cumulative Capital Requirements
by Facility Grouping, 1978-2000
Reference Case
(Millions of January 1978 Dollars)

	Total	%Total Capital	%Domestic
Oil			
Exploration, Development, & Production	3211.150	23.0	33.0
Refining	1572.815	11.3	26.1
Pipelines	20.086	0.1	30.0
Tankers, Barges, Trucks	277.660	2.0	24.9
Bulk Stations	47.068	0.3	51.1
Other	221.944	1.6	28.0
Total Oil	5350.723	38.3	30.5
Gas			
Exploration, Development, & Production	14.166	0.1	25.5
Pipelines	0.0	0.0	0.0
Distribution	49.893	0.4	40.0
Other	0.0	0.0	0.0
Total Gas	64.058	0.5	37.5
Coal			
Mining	119.828	0.9	30.0
Transportation	3.179	0.0	16.1
Total Coal	123.007	0.9	30.1
Electric Utilities			
Conventional Hydro	552.779	39.4	32.2
Mini & Micro Hydro	110.672	0.8	91.0
Combustion Turbine	196.901	1.4	20.8
Diesel	720.024	5.2	24.9
Other Oil & Gas Fueled	23.908	0.2	29.2
Conventional Coal-Fired	448.460	3.2	26.1
Sulfur Removal	0.0	0.0	0.0
Heat Recovery	27.862	0.2	27.6
Geothermal	0.0	0.0	0.0
Nuclear	0.0	0.0	0.0
Other Generation	51.367	0.4	25.5
Total Generation	7068.056	50.6	31.7
Transmission	782.341	5.6	39.8
Distribution	590.240	4.2	70.7
Total Utilities	8440.636	60.4	35.1
Other Technologies			
Solar Water Heating	0.0	0.0	0.0
Other Renewable Energy	0.0	0.0	0.0
Total Other	0.0	0.0	0.0
Total Energy Industry	13978.44	100.0	33.3

Table 3.5-24

Summary of Selected Components of
Total Capital Costs, Reference Case
(Millions of January 1978 Dollars)

	2000	1978-2000 Yearly Average	1978-2000 Total	1978-2000 %Domestic
Non-Manual Technical Manpower	17	12	272	32.4
Non-Manual Non-Technical Manpower	1	0	11	100.0
Manual Manpower	47	31	717	72.4
Manpower Total	65	43	1000	61.8
Materials Total	226	149	3421	46.9
Equipment Total	324	243	5591	10.6
Total Capital Costs	871	608	13978	33.3

Table 3.5-25

Annual Costs for the Operation and Maintenance of Energy-Related Facilities, Reference Case (Million Dollars, 1978)			
	2000	1978-2000 Average	%Domestic
Non-Manual Technical Manpower	20	13	88.6
Non-Manual Non-Technical Manpower	8	5	100.0
Manual Manpower	62	39	93.4
Manpower Total	90	57	93.0
Materials Total	83	51	52.4
Equipment Total	104	66	23.0
Utilities Total	17	10	100.0
Services and Miscellaneous	51	34	73.8
Annual Operating Cost (ex. fuel)	345	217	59.6

Source: Annex - 10

3.6 Uncertainties: As we described above, the Reference Projection creates a single view of the future evolution of the energy system, and, in particular, it creates detailed pictures of the system in the years 1985 and 2000. To establish these pictures, assumptions must be made on the future industrial mix, rural-to-urban migration, industrial energy efficiency, and other economic, demographic, and energy parameters. Since Peru has a number of possible futures, even if current government plans are implemented, some uncertainties cannot be avoided. Thus, before using the Reference Projection as the "benchmark" against which energy options are analyzed, it is essential to identify the variations that would result from the use of alternative assumptions.

Uncertainties in the future oil production and consumption levels are of particular importance, since in the reference projection oil accounts for 65 percent of commercial resource use in the year 2000. Figure 3.6-14 compares the projected oil consumption in the Reference Case with the projections of oil production that were discussed in Section 3.0. In order to reflect the uncertainty of future oil demand, an uncertainty of $\pm 1/2$ percent was applied to the annual growth rate of oil consumption in the period between 1976 and the year 2000, which is equivalent to a variation of $\pm 45,000$ barrels per day in the year 2000. As shown in the same figure, oil production is expected to exceed domestic requirements until about 1985. Beyond that point, the production curve has a wide range and depends on near-term investments in exploration and production drilling. The different possible oil production and consumption combinations have very different economic implications. For example, assuming Reference Case production levels (318,000 barrels per day), the variation of $\pm 1/2$ percent in the consumption growth rate is a difference between importing 26 million barrels (at a cost of \$350 million, even at current world oil prices) and exporting almost 7 million barrels in the year 2000.

In this section, several of the more significant uncertainties are examined in a quantitative manner, with an emphasis on those relating to oil.

3.6.1 Rural Fuel Mix: In the Reference Projection, we assume that there will be a gradual increase in the use of kerosene in the rural areas for cooking and other domestic needs, replacing the use of firewood and similar fuels. An alternative view is that recent and future increases in kerosene prices, the very high markup charged by kerosene distributors, and the continued availability of wood in most areas will prevent this shift. This alternative scenario (detailed in Appendix B) lowers the demand for petroleum products in the residential sector by 20.7×10^{15} joules in the year 2000. This drop represents almost 20 percent of the projected demand for oil products in the residential sector, but it amounts to less than 3 percent of total projected oil demand. On the other hand, this decrease would lead to a significant increase in the amount of firewood and other noncommercial fuels used. Instead of dropping by almost one third from 1976 levels, as in the Reference Case, their use would increase slightly by the year 2000. From the point of view of resource availability, no constraints are envisioned for such levels of consumption of noncommercial fuels.

FIG 3.5-14 COMPARISON OF PROJECTED OIL CONSUMPTION AND PRODUCTION.

3.6.2 Transportation oil consumption: Deviations from the Reference Case projections of oil consumption in the transportation sector may come about because of the effects of fuel prices increases, especially those for gasoline. Large increases instituted later than 1976 (the base year) had visible effects on demand but were not accounted for in the Reference Projection. Because the price increases in the period 1977-78 coincided with a recession, it is not possible to separate the effects on demand due to the economic downturn from those caused by the price increase. Nevertheless, the total impact of these two effects can be estimated. To do this, an alternative projection was prepared (Appendix B) using estimated 1978 gasoline sales as a base. Applying the same growth rates for the different transportation modes as in the reference projection to the 1978 figures yields demands for the transportation sector that are lower by 63.0×10^{15} joules in 2000. This represents an 18 percent decrease from the Reference Case for the transportation sector, amounting to over 8 percent of total oil demand in the year 2000.

3.6.3 Industrial expansion: The industrial sector projections are firmly linked to economic subsector growth rates that were obtained from documented sources, and these will usually be accurate in the near- and mid-terms. However, countries like Peru, which depend heavily on export of commodities, have historically been subject to very cyclical growth patterns; the assumption implicit in the reference projection is that the economy will sustain an average growth of 5 percent per annum, although observed growth may show pronounced fluctuations. The reference projection is likely to be very sensitive to this assumption, and different development paths could affect future energy consumption significantly.

An example of a future resource requirement linked to assumptions on industrial development is the case of coal, where a nearly ten-fold increase in use in the iron and steel sector is included in the Reference Case. Over one-half of the projected coal demand in 2000 is destined to the iron and steel industry; therefore a change in industrial development plans could have a large impact on coal use.

3.6.4 Migration patterns: The reference projection incorporated a continued rural-to-urban migration that in energy terms implies a shift from the use of firewood and other noncommercial fuels to kerosene and electricity. While the statistical evidence today points to a continuation of this trend, the Peruvian government has a stated policy of decentralization and reversal of the internal migratory trend. Since this reversal will take place only with rapid rural development, the analysis presented here is effectively an initial view of the energy impact of rural development. In the event that these policies are successful in the mid- and long-term, the projections of urban and rural households used in the analysis would be in error. They would also affect the transportation sector, by greatly reducing the growth in urban mass transportation needs (buses) and the growth in freight (due to a decrease in the movement of foodstuffs to urban areas, which in part may be offset by an increase in the flow of consumer durables to rural areas).

The effects on energy demand of arrested rural-to-urban migration are a 12 percent decrease in total oil demand and a 9 percent decrease in electricity demand. Noncommercial fuel usage would triple projected Reference Case levels and double historic levels. (These impacts, which were obtained in a very simplified manner, assume no change in the nature and energy use of the rapidly growing industrial sector, a condition that might not be achieved in a scenario that postulates intensive rural development. Thus, the analysis presented here should be viewed only as an exploration of the sensitivity of the Reference Case to the issue of internal migration.) On a sectoral basis, the impact of this case is large. Petroleum used in the household sector would decrease by nearly one half, and in the transportation sector by more than 10 percent over the Reference Case. Electricity supplied by conventional sources to households would drop 25 percent (this would have to be offset by isolated generation, through mini-hydro probably, as a sinequanon for rural development). However, the trebling of demand for energy from noncommercial sources does not necessarily signify a trebling of the amount of noncommercial fuels burned. Through improvements of the efficiency of the devices used to burn these fuels, and development of other technologies such as biogas and wood gasification (see Section 4), firewood and farm wastes use could be maintained at historical levels in spite of the increase in demand for energy from these sources.

3.6.5 Electricity demand: There appear to be significant differences among various electricity demand projections. The Direccion General de Electricidad of the Ministry of Energy and Mines publishes electricity demand projections, the most recent of which (from 1978) forms the basis of the capacity expansion plans used in the Reference Case. (Future consumption of electricity in the Reference Case, however, is obtained from the analysis detailed in Appendix B.) Earlier projections made in Peru are considerably higher than the Reference Case. The projection of October 1977, cited in Annex-5, yields by extrapolation a total of 48,000 GWh to the year 2000. This is substantially higher than the 29,600 GWh in this report. The very high growth rate implied by this level of consumption is very unlikely to be realized, but it is not without historical precedent in an international context. Moreover, these high estimates would yield a per capita electricity use of only one-fifth the level that exists in developed countries.

The high penetration of residential electrical appliances, which are already incorporated in the Reference Case, precludes significant additions to electricity consumption in that sector. Thus, most of this additional electricity would be utilized in an industrial sector more than double the size of that projected in the Reference Case. The creation of such a large number of electricity-intensive industries is not likely to occur over the assessment period. However, Peru's large hydroelectric potential presents an attractive possibility in the long term, as alternative sources of energy, such as oil, become increasingly scarce. Indeed, it is probable that Peru will find electricity-intensive industries and exports to be attractive investments in the years after 2000.

Notes and References for Section 3

1. Instituto Nacional de Planificacion, Short Term Plan - draft of mid-1978.
2. The INP's draft short term plan implies an average growth rate of 3.04 percent per year for the period 1976-1985. However, if the economy's poor performance in 1978 is taken into account, the INP draft plan implies a growth rate of 2.65 percent per year. The plan available at the time of this writing was prepared before the magnitude of the GDP decrease in 1978 was clear. The INP further projects a recovery from the recession in 1979. However, the economy's poor showing this year of -2 percent to -3 percent makes the assumption of recovery in 1979 appear less reasonable than it did at the time the plan was drafted.
3. Instituto Nacional de Planificacion, "Presupuesto Economico, Hipotesis a 1990," (Documento de Trabajo), Lima (1978)
4. Instituto Nacional de Planificacion, "Short Term Plan" op. cit.
5. Instituto Nacional de Planificacion, "Presupuesto Economico" op. cit.
6. Barry G. Tunnah, "Report on Industrial Sector Demand of Peru," Annex-2 to this report, September, 1978.
7. Ibid.
8. Ministerio de Energia y Minas, Direccion General de Electricidad, Direccion de Desarrollo Electrico, "Plan de Electrificacion Nacional, Segundo Reajuste, Periodo 1978-1990," Lima, Peru, December 1977.
9. On the basis of the analysis of future electric system loads, the installation of a nuclear power plant on any of ELECTRO PERU's integrated subsystems will be inappropriate from an electric systems engineering standpoint until the year 1996, at the earliest. (The limitation is in the size of the largest facility on a grid relative to the total size of the subsystem.) Seismic considerations may also prove important in limiting the application of nuclear power, because the cost of the design features that are required to compensate for the high seismicity that characterizes much of Peru will be high.
10. Bechtel Corporation, Annex 10 to this report.
11. Ministerio de Energia y Minas, Oficina Sectoral de Planificacion, "Plan Energetico a Largo Plazo 1978-1990 y Perspectivas al 2000, Diagnostico 1968-1977," Lima, Peru, July 1978.

4.0 THE DEVELOPMENT OF STRATEGIES AND OPTIONS

4.1 Introduction

The previous sections of this report have described the current energy supply and demand situation in Peru and expected developments over the next 22 years. This section identifies the major concerns or issues that emerge from that picture and evaluates the role that the application of various amounts of other available energy resources and applicable technologies could play in Peru's energy future. This evaluation is presented as an initial basis on which the Government of Peru could formulate energy development policy and define programs for the development of alternative energy resources and applicable technologies.

4.2 Approach - The Analysis of Options

In the course of this preliminary analysis of the energy situation in Peru, five alternative energy strategies of potential importance were identified. The formulation and analysis of the strategies in all cases is preliminary, and each requires further analysis and definition. However, each has been explored in sufficient depth to give one an appreciation of its potential contribution.

The term "strategy" refers to a specific energy policy direction, such as the increased use of renewable resources. A strategy is defined as a set of energy options that are combined and implemented at specified levels. In some cases there are a number of technical and resource options that can contribute to a given strategy. For example, considerations in the strategy defined as the increased use of renewable resources are the use of biomass-derived fuels, other uses of solar energy, wind power, geothermal energy, and small-scale hydro power. The analysis is concerned primarily with the technical and economic feasibility of options that can contribute to the accomplishment of a strategy, rather than the policy instruments to implement them. For example, the energy conservation strategy deals with the technical and economic feasibility of the technological process changes, but not with energy pricing policies that would tend to induce those changes or to reduce levels of activities that use energy. One exception is the last strategy analyzed, which is a combination of all technological options considered in the analysis up to that point. An additional reduction in future oil demand is incorporated to reflect the observed effects of Government gasoline pricing policy and other measures instituted since 1976, designed to reduce gasoline demand.

Each strategy is analyzed by examining the individual options which can contribute to it. The option is characterized in terms of the maximum reasonable rate at which the technology could be implemented (if it were given adequate financial support), its costs, infrastructure requirements, and manpower needs. The analysis specifies exactly how the technology would be implemented in terms of both the particular point in the Reference Energy System that would be affected, and the quantities of particular fuels to be displaced. Since most energy projects require a substantial amount of time to plan, design, construct, and so forth, most of the options that are considered could have only a very minor impact by 1985. As a result, the year 2000 is the most revealing for the purpose of analysis.

4.3 Strategies

The five alternative strategies that were formulated are based on variations from the Peruvian Reference Case. These strategies are differentiated by the extent to which various indigenous resources are used to reduce oil consumption, while satisfying the energy needs of Peru in a way consistent with the economic and social development goals that have been articulated by the Government of Peru.

None of the strategies considered in this assessment includes a nuclear component, since a nuclear power plant on which construction started in 1995 (the earliest date under current Peruvian plans) would not begin operation before the year 2000, if current experience is indicative of future action. Indeed, Peruvian plans call for construction to start at that point only if nuclear enjoys advantages over hydropower, which it would then replace.

4.3.1 Increased use of renewables: (Increased Renewables)*

The increased renewables strategy envisions the effects of the vigorous implementation of energy technologies that use renewable resources.

The technologies considered in this strategy are: electricity from geothermal energy, small-scale hydro power, solar water heating, solar photovoltaics, wind turbines, charcoal, biogas digesters, gasification of wood wastes, and ethanol from sugar cane, although some of these are projected to make only limited contributions. (While conventional hydro power is normally considered to be a renewable resource, its role in Peru is so important that it merits separate treatment. See Section 4.3.3.). Generally optimistic assumptions on resource availability and implementation possibilities of these technologies have been made in this analysis.

The implementation of renewable options in rural areas increases overall energy supply in Peru, which supports social and economic development that was not envisioned in the Reference Case. Because the energy demand filled by these options is now either met by noncommercial fuels or is not met at all (*i.e.*, some is "new demand"), the impact on total oil consumption by the year 2000 is slight, amounting to a decrease of less than three percent from the Reference Case levels. This criterion falls short of measuring the real impact of implementing these technologies on rural development and electrification. Figure 4.3-1 quantifies the differences in energy flows between the Reference Case and this strategy, and Figure 4.3-2 shows the changes in resource use in the year 2000.

4.3.1.1 Introduction: Renewable resources have the potential to contribute significantly to meeting Peru's future energy needs beyond the year 2000, especially in rural areas where more than half of the country's current population is located. The potential contribution of renewable resources to meeting the demands of the urban and industrial sectors is much more limited in the interval under consideration. This is because the technologies using renewable resources are not economically competitive with existing centralized systems for these purposes. (Certain specific technologies, such as geothermal energy and biomass-derived

* Entries in parentheses are the short titles for the strategies in the figures and diagrams.

FIGURE 4.3-1 RENEWABLES STRATEGY MODIFICATIONS IN ENERGY FLOWS FROM REFERENCE CASE—PERU.

liquified fuels, may be exceptions to this.) Another difficulty is that Peru's major urban area (the Lima-Callao metropolitan region, which contains almost a quarter of the country's population) has relatively little solar and wind availability.

Like those of many other developing countries, Peru's rural inhabitants rely almost completely on foraged wood for their energy needs. Most villages and settlements currently lack access to electricity, and there is no plan to link them to the grid in the foreseeable future. This is also true for many of the smaller mining settlements. Unlike the situation in some other developing countries, however, the availability of wood does not appear to be a constraint, except perhaps in some localized areas. The lack of other energy forms capable of being used more efficiently and productively acts as a barrier to rural development. Several studies (e.g., Revelle, Makhijani, UNEP) have demonstrated that in many developing countries an increase in the supply of useful energy to the rural sector is necessary to raise agricultural productivity and provide basic amenities. The prospect of using the standard commercial energy sources (oil products and central electricity supply) to provide this increase in Peru is limited, both by the prohibitive investments involved in rural electrification from a grid and by the overall shortages in oil that are likely to occur over the next two decades. In this context, renewable resource technologies can make a useful contribution toward increasing energy supply to the rural sector at costs which are already lower than petroleum-based alternatives in some cases. It should be emphasized, of course, that an increase in energy supply alone, whether from renewable sources or fossil fuels, is no guarantee that rural development will in fact occur.

In order to be successful, renewable energy resource technologies should be carefully matched to the pattern of current and projected energy needs and uses. In addition, the entire renewables strategy has to consider the potential economic, social, and ecological impacts on the region. This is particularly the case for various biomass schemes, which involve complex social and environmental trade-offs between existing patterns of land use and land used for energy production. It is also the case for the mini-micro hydro power option, where there are competing demands for water resources and an existing set of rights associated with their use. It cannot be overemphasized that a strategy of using renewable energy resources should be developed in the framework of a comprehensive planning effort that sets up various development criteria and a mechanism for impact evaluation.

Sections 4.3.1.2 through 4.3.1.5 present a preliminary evaluation of various renewable options in the context of Peru's resource base with a very brief assessment of social and economic considerations. Implementation of many of these options will require a careful planning effort at the regional level, where the impact of each option can be assessed within an overall development strategy.

4.3.1.2 Geothermal: Appendix B.1 describes Peru's most promising geothermal resource areas. For the purposes of developing an analysis of this option, it was assumed that adequate geothermal reserves would be identified

FIG. 4.3-2

IMPACT OF ENERGY STRATEGIES IN 2000,
INCREASED USE OF RENEWABLES

among potential areas around Cuzco, Puno, Arequipa, Moquega, and Tacna. There are two specific sites in southern Peru that could be sites of preliminary exploration. The first is Calacoa, where the character of the hot springs indicates subsurface temperatures high enough for electricity production. The second is at Salinas near Arequipa, where the general geologic environment appears favorable, although there is no direct evidence yet for a high temperature geothermal reservoir.

To utilize geothermal energy economically for electricity production with currently available technology, minimum underground temperatures of 170°C to 200°C are required at depths less than 3 km. Furthermore, hot water or steam must be encountered in permeable zones (reservoirs) in the hot rock because the thermal energy has to be transferred to the surface by withdrawing that water or steam. Power plant turbines have to be located close to the wells, and turbine design and size have to take into account conversion efficiency as well as conditions of operation that would allow maximum utilization of the available resources over an extended time period.

The development and implementation of the geothermal option requires exploration and resource evaluation leading to the installation of a 10 MWe demonstration plant to be in operation by 1988. Assuming the demonstration plant proves successful, the next step would be the introduction of a commercial-scale plant via one or more units totalling 50 MWe in or near the demonstration plant field by 1996. Thus, by the year 2000, a total of 60 MWe should be available from implementation of the geothermal option.

Assuming that the geothermal plants function at an overall 50 percent capacity factor, the annual production of electricity would be 263 Gwh or 0.95×10^{15} joules of electric energy. If this electricity were to be produced from oil-fired plants, it would require about 3.2×10^{15} joules of primary fossil energy or about 800,000 barrels of oil annually. Hence the savings in oil from implementing the geothermal option would amount to 3.2×10^{15} joules.

The cost of electricity production from a geothermal hot water system with a reservoir temperature around 200°C is estimated to be 25 to 30 mills/kwh, or about 0.6 to 0.7 soles (1976) per million joules. The capital costs are about \$700 per installed kilowatt of capacity, a favorable comparison with the capital costs of central station fossil-fueled, nuclear, or hydro plants.

Geothermal plants can have definite negative environmental impacts. In many cases, the waste waters from geothermal sites contain a variety of toxic chemicals that must not be permitted to contaminate surface or ground water used for agricultural or domestic purposes. Land subsidence is also likely to occur around geothermal reservoir sites, which could have serious effects on agricultural systems or on buildings and industries in the vicinity. Most of these impacts, however, can be minimized with proper siting and operational procedures.

Geothermal sites are likely to be developed in Peru at relatively high elevations in the Andes, in the same general region as a number of mining operations that require electrical power and now generate it from captive diesel generators. Oil is expensive and difficult to transport to these mining areas, and geothermally generated power would be an attractive substitute. Hydro power may be an economically attractive alternative to geothermal power on a site-specific basis.

4.3.1.3 Small scale hydropower: Hydropower is one of the most promising options for decentralized electricity production in the villages and secondary towns of Peru. There is a large number of potential sites in the vicinity of inhabited areas, both in the Sierras and in the Ceja de Selva. Sites in the Sierras are characterized by the high falls (or heads) and low-to-moderate flows that are associated with the use of canals for irrigation. In the jungle region, the hydro resource is typically low head and high flow.

Incomplete 1972 census data suggest that there are over 3000 villages in the mountains and the jungle, with a total population of over four million. About 100 of these villages are fairly substantial settlements with populations of between 6,000 and 10,000. Ninety-five percent of these villages do not have electricity. Of the remaining five percent, one percent obtains it from hydropower stations and the remainder from diesel/gasoline generators. In spite of the relatively low capital cost and easy installation of diesel generators, the high costs of fuels and lubricants, the short operating life, and the specialized maintenance required make them impractical for expanding rural electrification.

The basis for evaluating the impact of the mini-hydro option is the number of villages and small towns that are not now electrified and have hydro resources. Table 4.3-1 outlines the distribution by size of villages which are assumed to possess hydro resources. To obtain an estimate of the electricity generation requirements, it was assumed that required installed capacity per capita was 25 watts in Group A, 30 watts in Group B, and 35 watts in Group C. This gives a range and average size for the installations in the villages in Groups A, B, and C, as shown in Table 4.3.2.

Assuming that about 10 percent of the villages in each group would incorporate themselves into installations constructed for the next higher group through a "mini-grid," the total number of mini-hydro stations and their installed capacity by group size is shown in Table 4.3-3.

Table 4.3-1.

Villages Assumed to Possess Hydro Resources*

Group	Population Range	No. of Villages	Population (Thousands)
A	200 - 1,999	1,920	1,400
B	2,000 - 5,999	360	1,300
C	6,000 - 10,000	<u>72</u>	<u>550</u>
TOTAL		2,352	3,250

*Based on estimates made by E. Indacochea of ITINTEC.

Table 4.3-2

Estimate of Required Electricity Generation

Group	Range of Installed Capacity (KW)	Average Size (KW)
A	5 - 50	30
B	50 - 179	120
C	180 - 350	270

Table 4.3-3

Number and Capacity of Mini-Hydro Stations

Group	Aver. Installed Capacity (KW)	No. of stations.	Installed Capacity (MWe)
A	30	1,728	52
B	120	368	44
C	270	<u>90</u>	<u>24</u>
TOTAL		2,186	120

The total installed capacity in 2000 under the mini-hydro option is 120 MWe. Electricity requirements in rural areas are generally characterized by low load factors, in the range of 10 to 20 percent. Agricultural demand arises largely from irrigation water pumping, a highly seasonal activity, while domestic demand is likely to be largely for lighting, at least in the initial stages of electrification. Assuming an annual load factor of 20 percent, the total electricity consumed based on the 120 MWe installed capacity will be about 210 Gwh in the year 2000, or 0.75×10^{15} joules.

Another sector in which mini-hydro plants are potentially very useful is that of small mining establishments. There are now about 800 small mines in Peru (down from 1200 a few years ago, because of the current economic situation). There are also some 60 concentration plants for ore from small mines. About 20 of these plants obtain electricity from hydro power; the remainder use diesel generators. Assuming that the number of small mines and concentration plants grows at about three percent per year from 1980 to 2000 (following the economic recovery), there will be approximately 1500 such mines and about 110 concentration plants serving them in the year 2000. On this basis, 67 MWe of capacity generating 180 GWh of electricity annually would be installed by the year 2000.

Thus, the total energy contribution from mini-hydro power systems could be an installed capacity of 187 MWe generating 390 GWh of electricity annually, equivalent to 1.4×10^{15} joules of electric energy. In terms of fossil fuel equivalences, the same amount of electricity generated by small diesel/gasoline generators would require about 6.5×10^{15} joules of primary energy fuels, which is equivalent to a little over one million barrels of oil.

The installation cost of mini-hydro power systems is expected by Peruvian officials to average \$500 per installed kilowatt, assuming that labor is free to complete the necessary civil works. The capital cost can be expected to vary considerably, depending on the head, the size of the installation, the availability of a structure to serve as a powerhouse, and the sophistication of the plant. The average cost of \$500/kw is based on the actual experience of installing a micro-hydro (4kVa) Mitchell--Banki turbine in a pilot plant in the rural community of Obrajillo near the town of Canta, 65 miles from Lima, by ITINTEC.

Mini-hydro stations have no known generic adverse environmental impacts, but careful attention has to be given to soil stability in civil works and canals. Furthermore, downstream users have to be protected against possible loss of water if the mini-hydro station requires construction of a reservoir to generate power.

Successful implementation of the mini-hydro option will require more complete definition of the actual demand for electric energy and the hydro power resources available in rural areas (villages and mines) than is currently available. Moreover, Peruvian capability to design and manufacture Pelton and Mitchell-Banki turbines and ancillary generator equipment, along with standardization and interchangeability of various components, must be established if the cost is to be kept within \$500 per kilowatt.

4.3.1.4 Solar and wind: Despite its proximity to the equator, solar availability in Peru is highly variable. High levels of the incidence of sunlight (insolation) are predominant in some coastal and Sierra regions (such as the regions around Piura, Puno, and Arequipa), but the Lima-Callao metropolitan region has persistent cloud cover for at least six months of the year.

The solar and wind option is divided into two categories: (1) solar water heaters in those urban areas that have good insolation, mining towns, and rural areas; and (2) solar photovoltaic systems and wind turbines to generate electricity and to pump water in rural areas that lack hydro resources and are connected to a grid.

a. Solar Water Heaters

Although water heating is a comparative luxury in Peru, even in urban areas, about 20,000 water heating units (mostly electric, but some using bottled gas) are currently sold annually. This number is expected to increase with a rise in general living standards. Moreover, the larger mining concerns are required under Peruvian law to provide hot water to about 60,000 miners and their families in the company towns. Hot water use for personal washing is not common in the Sierra or other rural areas. However, there is a definite need for hot water in public facilities, such as primary health centers and schools.

The solar water heating option thus foresees the increasing use of solar collectors for heating water in three areas:

1. urban areas (outside Lima): domestic residences and institutional and commercial establishments, such as hospitals, dormitories, schools, shops, offices, etc.;
2. mining towns: residences of mining workers; and
3. rural areas: public facilities, such as health centers and schools.

By the year 2000, about 200,000 collectors, of an average size of 20 square feet (1.9 sq. meters) each could be installed, with 60 percent of these in urban areas, 30 percent in the mining towns, and 10 percent in the rural areas. The total annual output of energy would be 0.63×10^{15} joules, of which 0.37×10^{15} joules would represent savings of oil and 0.22×10^{15} joules savings in electricity. The balance represents a net increase in energy demand that arises from the availability of this option.

Solar water heating is a straightforward and established technology, and it could easily be implemented in Peru with currently manufactured equipment. However, creating a market in Peru could present a problem, and active government participation through subsidies, for example, would probably be required. In urban areas and mining towns, the use of solar water heaters could displace the consumption of bottled gas, kerosene, and electricity that are now used for heating water. Systems installed in rural areas have the potential to improve general hygiene without increasing kerosene consumption.

b. Solar Photovoltaics and Wind Turbines

Solar photovoltaic systems could be used to provide small-scale electricity for pumping water and powering communication equipment in rural areas without a viable mini-hydro resource. Over the longer term, photovoltaics could replace or supplement power produced by diesel generators in isolated areas that are not expected to be linked to a grid.

The basic limitation of current photovoltaic applications is the high cost of the solar cells themselves and the need for expensive battery storage. The implementation of this option assumes that cell costs will decline in the next few years to a level where photovoltaic-generated electricity is competitive with remotely located diesel generation. Moreover, in many small-scale rural applications, such as water pumping, storage requirements should be minimal.

The photovoltaics option assumes that there will be 59 MWe (peak) of cumulative installed capacity by 2000. At a capacity factor of 0.25, 120 GWh of electricity (0.45×10^{15} joules of electric energy) will be generated annually.

Wind turbines serve much the same end-use sectors as solar photovoltaics. In addition, wind-powered pumps can be directly used for pumping water. A basic difficulty in evaluating the wind option is that Peru's wind resources

are not well known. Although some of the coastal regions are known to have windy areas, such as Piura where small wind-powered water pumps have been used for a number of years, no well-defined measurements exist for the country as a whole. As a result, the development of the wind option assumes that a proper resource evaluation will discover enough windy areas to justify installation of wind turbines.

The wind option assumes that there will be about 3000 small systems in the 1-25 KW range (with an average capacity of 10 KW) and 250 large systems with an average rated capacity of 100 KW by the year 2000, which will provide a total rated capacity of 57 megawatts. At a capacity factor of 0.33, this would produce about 144 GWh of electricity (0.51×10^{15} joules).

In the foreseeable future, Peru will need to import solar cells as well as blades, and possibly generators for the larger wind turbines. However, the manufacture and assembly of the remainder of the equipment for these options could be easily undertaken in Peru.

No significant environmental impacts should occur at the levels of implementation in these scenarios.

4.3.1.5 Biomass: Four elements comprise the biomass option:

(a) Production of charcoal from existing wood supplies for use as a fuel in households in secondary cities, towns, and villages, and in small cottage industries such as brickmaking and roof tiles. Charcoal would be produced in small stationary or mobile pyrolytic units of simple design, with an average capacity of one tonne per day. A total of 2300 units is envisioned in the year 2000, producing a total of about 850,000 tonnes of charcoal annually, with an energy content of about 24×10^{15} joules. A quarter of this, or 6×10^{15} joules, would be used in the small towns where it would displace kerosene on a joule for joule basis. The remainder would be utilized in rural villages where it would substitute for existing wood use. The main objective of using this technology for rural villages would be to provide a higher quality fuel (especially to cottage industries) that can be used more efficiently and to decrease the amount of time the village population spends gathering fuel.

(b) Anaerobic digestion of animal dung and agricultural residues to produce fuel gas (60 percent methane) and fertilizer, an attractive opportunity for a number of Peruvian villages. The gas can be used for cooking, lighting (in a gas mantle lamp), or for operating modified internal combustion engines. The technology is relatively simple and has been developed at the village level in a number of developing countries in Asia (notably China, but also India, Taiwan, and the Philippines). The option envisions the construction by the year 2000 of 1000 small household-size digesters capable of producing 100 cubic feet of gas per day and 100 community-size digesters producing 1000 cubic feet of gas per day. The total energy value of the gas produced would be 0.2×10^{15} joules. In addition, the digesters could produce an aggregate of about 20,000 tonnes of rich (average nitrogen content of around 2 percent) organic fertilizer annually.

Biogas digesters have a beneficial environmental impact in that they provide a sanitary means of disposing of human and animal wastes. (Adding human wastes to animal dung/agricultural residues actually increases gas production.) The only major hazard associated with biogas plants is the possibility of fire and explosion, since methane/air mixtures are explosive over a wide range of mixing. Adequate precautions against fire and explosion must therefore be taken in the production and utilization of the gas. There is a number of technical constraints on the proper operation of biogas digesters, such as ambient temperature and pH level. Gas production generally ceases below 15°C and this would make operation in the Sierra region problematical. In addition, there are the social and institutional problems involved in waste collection and management, which would have to be carefully investigated before the option can be fully developed.

(c) Gasification of wood wastes to produce a low BTU gas for generating electricity and steam at existing lumber mill sites. This technology is relatively simple, well-developed, and easily implemented. A number of lumber mills have been identified whose requirements for electricity/process steam are currently met by fuel oil. These mills generate wood wastes that could be gasified to generate sufficient electricity and steam for the mills' own requirements. The generated gas would directly replace fuel oil. This option envisions the construction of 40 MW of electric capacity by the year 2000, based on 40 gasifier units of an average capacity of one MW each. Working on an average of 12 hours per day for 300 days a year, the gasifiers would generate 144 GWh (0.52×10^{15} joules of electric energy).

(d) Production of ethanol from sugar cane to use as a blended fuel with gasoline in motor transport. The technology for this is reasonably well-established, especially in South America, where Brazil's ambitious National Alcohol Program was projected to be producing almost three billion liters of ethanol a year by the end of 1978. Peru has a long tradition of sugar cultivation and is an exporter of sugar. Currently, Peru is reported to produce about 20 to 30 million liters of industrial ethanol from sugar. However, if ethanol from sugar is to make even a modest contribution to reducing gasoline consumption, the scale of production and the quantity of sugar allocated to ethanol will have to increase greatly. The commercial viability of doing this will depend on future oil production, future oil prices, and future world market prices for sugar, as well as the costs of producing ethanol itself.

A preliminary examination of the feasibility of this option suggests that it may be possible to set up a 20,000 hectare (ha) sugar plantation in the Tarapoto region and to dedicate its sugar production largely to ethanol production. Annual output of ethanol, based on raw cane production of 110 tons/ha, could reach about 140 million liters (a little less than one million barrels). If the ethanol is used in a 10 or 20 percent blend with gasoline, it would directly displace an equivalent amount of gasoline.

As a result, the savings in oil under this option could be about 6×10^{15} joules. However, a thorough analysis of the economic feasibility and the social and ecological impacts of establishing a sugar plantation in the Tarapoto area must be conducted.

4.3.2 Increased energy efficiency: (Increased Efficiency)

The increased energy efficiency strategy envisions the widespread application of more efficient devices and processes in the energy-consuming sectors of the Peruvian economy. It is unique in that it does not rely on an alternative supply source to achieve decreases in oil consumption. Thus, activity levels and assumptions about resource availability that are used for the Reference Case remain unchanged in this strategy. The configuration of the energy system is modified only in that selected industrial processes are modified to require less heat and electric power, and a change into more efficient transportation vehicles takes place. Total petroleum consumption drops by 10.1 percent, 48 percent of which is attributable to the transportation sector and 52 percent to the industrial sector. Figure 4.3-3 shows the changes in energy flows in the year 2000 that would result from the implementation of this strategy.

4.3.2.1 Introduction: The final step in converting the chemical energy of fuels into useful work is made through the end-use devices (boilers, internal combustion engines, stoves, etc.). Improvements in the efficiencies of the end-use devices are perceived worldwide as one of the best ways to alleviate energy shortages in the short- and medium-term. The rate of penetration of improved devices depends on the investment cost, institutional constraints, and demand for the product, although proper maintenance of equipment can also contribute to higher efficiencies and does not require capital. Energy use patterns in households are generally less amenable to government policy than is the profit-making industrial sector. The depreciation allowed for capital equipment in Japan, for example, is a major factor in the proliferation of up-to-date, energy-efficient processes in that country. In general, no evidence of large-scale energy "wastefulness" in Peru was found, yet to the extent that energy-efficiency improvements develop at the international level, Peru will benefit in its traditional role as a recipient of foreign technology. Figure 4.3-4 shows the impact of increased energy efficiency on the use of energy resources in the year 2000.

4.3.2.2 Industry: The potential impact by the year 2000 of a major program to improve energy efficiency has been estimated using the basic data on industrial energy consumption that was developed in Section 3 of this report. The energy saving potential for each of the subsectors is derived as follows:

FIG. 4.3-4 IMPACT OF ENERGY STRATEGIES IN 2000, INCREASED ENERGY EFFICIENCY

a. Existing Plants and Those Operating by 1985

For existing plants and those brought into operation by 1985, the United States' program of energy efficiency improvement targets was used to establish the assumed levels of energy efficiency. The following assumptions were adopted for each subsector, from which energy savings by the year 2000 were then estimated for existing plants.

1. Mining and Non-ferrous Metals. The target for improvements in energy efficiency in the non-ferrous metals processing industry is about 11 percent in 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 in Peru that are commissioned prior to 1985 (that is, a 16.5 percent savings).

2. Iron and Steel. The 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 use. Coke use in Peruvian industry is already quite efficient, and therefore a lower improvement (5 percent) was judged appropriate.

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

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

5. Chemicals. A figure of 10 percent was adopted for the Peruvian industry.

6. Fertilizer. 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 United States' target, was adopted.

7. Oil Refining. Savings of about five percent of energy use were judged possible through "housekeeping" and minimal capital investment programs by 1985, with a further five percent possible savings through investment in energy-efficient equipment, process changes, etc., by the same year. An additional five percent was judged achievable by the year 2000, resulting in a total savings by the year 2000 of 1.5×10^{15} joules/year. (Some of this is natural gas that is used as a fuel at Talara.)

b. Post-1985 Plants

For plants brought into operation after 1985, which presumably would be designed to include the best available modern construction practice, it was assumed that savings would total no more than 7.5 percent of their energy consumption by the year 2000. These savings would be obtained through the incorporation of the latest, most 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. A reduced level of savings (2.5 percent) was adopted for the coke that is used in the iron and steel subsector, because anticipated improvements will not have as great an effect.

Using these assumptions, potential savings by fuel type were estimated for the specified industries. The results are shown in Table 4.3-4.

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 electric generation, transmission, and distribution within the industrial sector of 25 percent, the electricity savings of 6.1×10^{15} joules therefore amount to a potential saving of 24.4×10^{15} joules of oil resources.

Table 4.3-4.

Estimated Annual Savings Potential by 2000

 $(10^{15}$ joules)

Area	Electricity	Oil	Gas	Coal/Coke	Total
Industry, general	1.8	7.5	1.1	0.5	10.9
Mining and Non-ferrous Metals	4.3	7.6	—	0.1	12.0
	6.1	15.1	1.1	0.6	22.9
Share of total demand for specified energy use (in percent)	11.7	10.1	10.1	3.7	9.1

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

Table 4.3-5
Annual Savings (10^{15} joules)

Oil	39.5
Gas	1.1
Coal	0.6
	<hr/> 41.2

4.3.2.3 Transportation: The Reference Case projections of total transportation energy use can best be analyzed by describing the four major sets of identified activities.

a. Intercity Highway Maintenance

The condition of the road network in Peru is now very poor. A recent study indicated that the effort to bring the primary road network up to a level at which regular maintenance could then preserve road conditions at acceptable standards would require about \$200 million for equipment and implementation. It is understood that this study, which was made for the Ministry of Transport and Communications, does not demonstrate the energy implications of such a program or those of a routine maintenance program. However, experience in other countries shows that considerable savings in vehicle-operating costs, including fuel, can result from road upgrading or improvement. A five percent energy saving, which should be considered to be very modest, would be equivalent to 7.7×10^{15} joules in the year 2000, when compared to the Reference Case.

b. A Mass Transit System for Lima

A study recommending the construction of a rail-based, electrified mass transit system in Lima was carried out in 1973, when factor prices had not yet adjusted to the energy crisis. The project has not been implemented for lack of funds, among other reasons. (Other projects designed to solve the urban congestion problem in Lima have been suggested. These include the construction of a monorail. This latter system, however, lacks the capacity of a

truly mass transit system and has not demonstrated clearly its effectiveness in other locations.) Such a mass transit system would allow a switch from petroleum to hydroelectric power and alleviate increasing urban congestion. Implementation of the system will contribute to an oil savings of 4.3×10^{15} joules in urban buses from improved energy intensity due to decongestion. Assuming that 15 percent of Lima's bus passenger-kilometers can be absorbed by the system in the year 2000 (some 6.0 billion passenger-kilometers), it would result in an oil savings of 6.0×10^{15} joules and an increase in electricity demand of 2.0×10^{15} joules.

c. Increased Efficiency of Transport Fleet

The reference projections assume that the intensities of energy use that were derived from all transport modes for 1976 remain constant through 2000. Since the rise in the price of oil, technological development in road and air transport have proceeded at a fast pace, and it is reasonable to expect that the Peruvian fleet will have improved its average intensity of energy use by 2000. The assumption here is that energy use drops by 5 percent for automobiles, trucks, and buses, and by 15 percent for air. Applying these figures to the projections (assuming (a) and (b) above are also implemented) yields a savings in petroleum products of 17.9×10^{15} joules.

d. Transport Management

Several measures can be taken which are roughly defined as falling within the field of transport management. These include the strict enforcement of speed limits on intercity roads, restrictions on engine size in private vehicles, encouragement of diesel over gasoline for trucks, and support for public transport and discouragement of private vehicles in central Lima through such measures as "park and ride" schemes, parking meters in central areas, dedicated bus lanes, and traffic engineering. These and other administrative measures could lead to significant savings, but they cannot be estimated with any precision without further study.

4.3.2.4 Residential and commercial: Energy consumption in the residential and commercial sectors does not appear to offer significant opportunities for efficiency improvements. Given Peru's climate, there will be no great long-term need for either air conditioning or heating. Cooking stoves allow for small savings, such as turning off pilot lights, and a switch from incandescent to fluorescent lamps also offers opportunities for energy savings. However, the most important fuel in these sectors is kerosene, which is used for cooking and lighting. The kerosene-fueled devices are very inexpensive and it is unlikely that major efficiency improvements can be obtained without substantial increases in the prices of the units. Potentially large decreases in kerosene consumption could be seen if a kerosene price increase is instituted (kerosene for domestic uses now sells for about 10 cents per gallon), but such an assessment falls outside this analysis.

The supply of firewood and other noncommercial fuels used in rural areas is considered to be adequate for the present in all but very localized areas, so that an incentive for increasing the efficiency of conversion does not yet exist.

4.3.3 Increased use of hydropower: (Increased hydropower)

The increased hydropower strategy envisions placing as much reliance as possible on hydroelectricity and a related shift to devices and processes that use electricity, rather than fossil fuels. It is projected that it will be practical to expand hydroelectric capacity by some 25 percent over the levels in the Reference Case. The structure of energy demand would change to electricity-based processes (e.g., in metallurgy) from the current fossil-fuel based processes. The impact on petroleum consumption in transportation (via a replacement of urban buses by an electric mass-transit system) and in industry amounts to a drop in total oil resource requirements of seven percent. Figure 4.3-5 shows the differences in energy flows between the Reference Case and this strategy.

4.3.3.1 Introduction: This strategy examines the implications of increasing the use of hydro-generated electricity as an energy source for Peruvian industry. This strategy is of particular interest because Peru is endowed with practical hydroelectric potential estimated to be at least 58,000 MW. The development of this resource as a substitute for fossil fuels could be of major importance in the years to come, as fossil fuels, particularly petroleum, become more expensive in relation to hydro-produced energy. Although capital requirements to harness the hydro potential by 2000 may exceed capital availability, efforts in this direction are extremely important to Peru's long-term development objectives. Figure 4.3-6 shows the impact of the increased use of hydro power on the use of energy resources in the year 2000. The overall issue may be divided into two distinct areas: (1) the conversion of existing fossil-fuel-intensive production capacity to electricity-intensive processes; and (2) the development of new industries in which process technologies demand an abundant supply of inexpensive electric power.

4.3.3.2 Process Conversion: The reference projection for the year 2000 contains an estimated 52.3×10^{15} joules of electricity that are required by industry, of which an estimated 13.2×10^{15} joules are self-generated ("autoproduktores"). The remaining 39.1×10^{15} joules would be supplied by public utilities. Eighty percent (or 10.6×10^{15} joules) of the self-generated energy would be generated from petroleum at an assumed conversion efficiency of 25 percent. Distribution losses amount to 10 percent. If 50 percent of this power could be supplied from hydro sources, the resulting oil savings in the year 2000 could reach 23.7×10^{15} joules. The corresponding hydro output of 5.9×10^{15} joules at a load factor of about 65 percent, would require a dedicated capacity of some 290 Mw. If hydroelectricity is not available to replace oil-fired capacity, such as is the case at Southern Peru Copper's Ilo smelters, the conversion potential would be correspondingly

FIGURE 4.3-5 INCREASED USE OF HYDRO POWER MODIFICATIONS IN ENERGY FLOWS FROM REFERENCE CASE—PERU, 2000

FIG. 4.3-6

IMPACT OF ENERGY STRATEGIES IN 2000,
INCREASED USE OF HYDROPOWER

smaller. The figure of 90 percent conversion to hydro by 2000 should therefore be regarded as illustrative, pending further study on limits of conversion potential.

An additional significant oil savings through increased use of hydro power could appear in the mining and non-ferrous metals industry. The reference projection includes an estimate of about 39.5×10^{15} joules of oil that are 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 processes electrowin copper from the ore, as opposed to the pyrometallurgical separation accomplished in the smelter. It is estimated that perhaps 50 percent of existing pyrometallurgical capacity could be converted by the year 2000, with a resulting oil savings of 19.8×10^{15} joules. Dedicated hydro facilities would have to be available in order to provide equivalent production levels.

The remaining potential for conversion to electricity is probably relatively small. 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.

There are also possibilities for increased electrification in the transportation sector. An electric mass-transit system in Lima that would consume 2×10^{15} joules per year would reduce oil consumption of urban buses by an estimated 10.3×10^{15} joules. Electrification of intercity rail systems could also have a significant impact on oil consumption, although this latter option would be more attractive for the planned coastal railway than for existing systems. However, further studies are needed before better estimates of the effects can be prepared.

4.3.3.3 Development of new industries: The potential for the development of new industries, based on abundant and cheap electricity, is less clear and not as easily estimated as is the conversion of existing fuel-intensive production capacity to electricity-intensive processes. Although the Government of Peru does not now have a concrete plan that could provide a basis for such an analysis, some current possibilities include:

- o production of electricity-intensive metals, such as aluminum, magnesium, titanium, and zirconium (Although Peru may not have domestic reserves of some of these minerals, the processing of imported ores for subsequent export may prove attractive.);
- o development of a steel industry based on pre-reduced iron ore;
- o production of high value-added products, such as ferroalloys, that may require nearly 4 Kwh per pound to produce;

- o production of calcium carbide (used in acetylene production) in electric furnaces; and
- o expansion of a nitrogenous fertilizer capacity based on nitrogen from air and hydrogen from water, as is now done at Cachimayo.

Such industrial projects share a common link: they are all extremely electricity-intensive. However, the lack of a definite industrial development plan at this time makes it impossible to produce good estimates of the energy that may be required by these industries by the year 2000 or over the longer term. In any event, one can conclude that Peru has more than enough hydro potential to satisfy these projected demands. While full development may require more capital resources than are now available, Peru's potential comparative advantage in electricity-intensive goods makes this strategy extremely attractive in the long term.

4.3.4 Increased use of coal

This strategy increases the use of domestic coal to replace petroleum in industrial uses. The Reference Case incorporates only one new use of domestic coal (an electric power plant). The strategy of increased use of coal explores the use of coal as a fuel for cement kilns, raising steam, and generating electricity in industry.

The increased use of coal will depend on the still uncertain availability of coal and its transportation to consumption centers. The utilization schedule outlined in this strategy calls for an increase in coal use of 26 percent and in domestic production of 37 percent; this assumes that one-half the coking coal needs will be imported. The impact on oil consumption is a drop of less than 4 percent from Reference Case levels. Figure 4.3-7 summarizes the changes in energy flows in the year 2000 that would result from this strategy.

An estimate of the nationwide potential for coal utilization cannot be made accurately until further exploration of the coal beds is completed. Coal exploration and analysis currently under way does not appear to be intensive enough to fill these requirements. Assuming sufficient supplies and attractive economics relative to petroleum, all oil-fired electricity and heating could be converted to coal-fired systems. However, in those areas where hydro potential exists, studies would have to be made on the relative costs of hydro and coal-fired electricity.

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 could also be investigated. Brazil imported 2.9 million tons of metallurgical coal in 1976 and may be a possible export market for Peru.

4.3.4.1 Introduction: Although Peru has indigenous coal resources, it currently imports virtually all of the coal and metallurgical coke that it uses. Peru's coal resources are not large by world standards,

COMMERCIAL FUELS

SEE REFERENCE 7 FOR DETAILS

NOTES:

1. FLOWS IN 10^{15} JOULES
2. SOLID LINE INDICATES REAL PROCESS
3. CONVERSION EFFICIENCIES SHOWN IN PARENTHESIS

FIGURE 4.3-7 INCREASED USE OF COAL MODIFICATIONS IN ENERGY FLOWS FROM REFERENCE CASE—PERU. 2000

but they could prove sufficient for Peru's needs for many decades and possibly substitute for the use of oil in some instances. Complete self-sufficiency in coking coal appears doubtful, though possibilities for production of blend coals seem promising. There is a lack of good, current data to substantiate reserve estimates, although past domestic production is well-documented. Figure 4.3-8 shows the impact on energy resources in 2000 of the increased use of coal.

4.3.4.2 Industrial power generation use: Essentially all of the electricity generated in the industrial and mining sectors is produced by oil-fired boilers, diesel generators, or diesel-fired gas turbines. This presents an opportunity for the replacement of petroleum by domestic coal sources for the medium- to long-term. However, coal-fired steam electric generation is impractical in small-scale applications, and a lack of distribution facilities could limit its use in factories around built-up areas. For this analysis, it was assumed that only the mining sector would shift to coal, because it is a sector which has relatively large electric plants and is experienced in the use of coal (e.g., for metallurgical processes). Substitution of 20 percent of the projected use of petroleum in electric generation in this sector amounts to an oil savings of 4.7×10^{15} joules.

4.3.4.3 Industrial process heat use: A substitution of 21.7×10^{15} joules of coal that replaces oil on a joule-for-joule basis in industrial process heat applications has also been included in the analysis for this strategy. It consists of partial or total shifts to coal in several industries that currently use petroleum. First, in the mining sector it was assumed that 10 percent of projected process heat requirements could be converted, amounting to 4.0×10^{15} joules. In the iron and steel sector, current oil injections into blast furnaces, which is estimated to be 12 percent of total petroleum use in this sector, could be replaced entirely by coal. In the year 2000, this would total 2.0×10^{15} joules. The third industry that could institute a shift is cement, for which it was assumed that 50 percent of projected kiln fuel demand would be converted, amounting to an oil savings of 14.5×10^{15} joules. Finally, it was assumed that the steamraising requirements in the chemical sector were met by coal, amounting to 1.2×10^{15} joules by the year 2000.

The heat requirements of a number of other industries, such as fertilizer and oil refining, could be met by coal, and it is theoretically possible to achieve greater oil savings than those estimated above. (Annex 2, Report on the Industrial Demand Sector of Peru identifies the potential impacts of those other possibilities.) However, we have cited only those that we believe to be most appropriate and likely in this section, and we believe that a variety of practical considerations will prevent the attainment of the maximum levels of coal substitution for oil.

4.3.5 Combined Strategies

This strategy examines the overall effects of the implementation of a combination of all of the options with an emphasis on reducing petroleum demand. Consistent with this objective, this strategy also includes the

FIG. 4.3-8

IMPACT OF ENERGY STRATEGIES IN 2000 INCREASED
USE OF COAL

modification of the Reference Case that uses the alternative fuel projections rural households and alternative demand projections for transportation. The alternative projections assume that there will be no growth in the rate of substitution of firewood by kerosene in rural areas, and use the year 1978 (rather than 1976) as a basis for projecting gasoline demand. Both alternatives result in a decrease in oil demand in the year 2000.

The modifications to the Reference Case are shown in Figure 4.3-9. They result in a decrease in oil demand of 220×10^{15} joules in the year 2000, a total drop of 28 percent. About 40 percent of this saving is obtained from the changed assumptions in the Reference Case projection and are not the result of implementing the other options that are described below.

4.3.5.1 Introduction: The strategy outlined here consists of an evaluation of the hypothetical implementation of all or most options described above. The purpose is to lessen domestic demand for petroleum by instituting increased energy efficiency and using renewables, coal, and hydro power, and then to balance this demand with optimistic levels of domestic production. The result yields either the possibility of exporting excess production or, at the least, lowering imports. Figure 4.3-10 shows the impact on energy strategies of increased petroleum production, plus lessened consumption in the year 2000. The combined strategy differs from the Reference Case and the other strategies in the following respect: activity levels in the transportation sector have been lowered to incorporate the effects observed by 1978 of Government policies designed to reduce gasoline consumption.

4.3.5.2 Production: The possible range of petroleum production levels in the year 2000 is broad. To obtain levels near the upper range of 320,000 barrels per day, large expenditures on exploration will have to be made in the near future.

4.3.5.3 Consumption: This configuration of lowered oil consumption incorporates the alternative residential and transportation projections that are lower than the reference projection for the year 2000, by some 83×10^{15} joules. The simultaneous inclusion of all strategies outlined above in the composite case raises the problem that the oil substitutions presented in the individual strategies are not necessarily additive. That is, the substitution for petroleum by coal cannot be added to the substitution for petroleum by hydroelectricity.

The analytical procedure chosen was as follows: the total contributions of the renewable resources were incorporated first, followed by substitutions of hydroelectricity and increased electrification. Increased use of coal was then introduced, followed by efficiency improvements on the remaining uses of petroleum. This results in a total decrease in oil consumption of 216.1×10^{15} joules in the year 2000. Some 40 percent of this drop is due to the incorporation of alternative projections, 8 percent to the inclusion of the renewables, 26 percent to increased use of hydro, 8 percent to increased use of coal, and 18 percent to increased efficiency. Table 4.3-6 summarizes these effects.

FIGURE 4.3-9 COMBINED STRATEGIES—MODIFICATIONS IN ENERGY FLOWS
FROM REFERENCE CASE — PERU 2000

**FIGURE 4.3-10 IMPACT OF ENERGY STRATEGIES IN 2000
COMBINED STRATEGIES**

Table 4.3-6

Substitutions of Petroleum by Implementation of Strategies

	Petroleum saved (10^{15} joules)	Comments
1. Alternative projection		
a. Residential	20.70	Firewood for kerosene in rural areas
b. Transportation	63.00	1978 as base year of projection
2. Renewables		
a. Alcohol production	6.00	Replaces transport fuels
b. Charcoal	6.00	Replaces residential fuels
c. Solar Water Heat	0.57	Replaces residential sector fuels
d. Geothermal, wind, photo-voltaics, wood gasification	7.80	Replace oil-fired electric generation
3. Increased hydro		
a. Electrify mining process	19.80	50% of potential substitution
b. Replace oil in self generation	23.70	50% of potential
c. Impact of electrified mass transit	10.30	
4. Increased use of coal		
a. Replace oil for process heat	17.70	Cement 14.5×10^{15} joules Iron and steel 2.0×10^{15} joules Chemicals 1.2×10^{15} joules
5. Increased efficiency		
a. Industrial process heat	13.30	Decrease of 10.1% in use
b. Electricity savings	2.80	Decrease of 11.7% in use
c. Transportation efficiency	<u>22.00</u>	
6. Subtotal	213.67	
7. Decrease in refinery consumption	<u>6.60</u>	
8. Total	220.30	

4.3.6 Summary

A central thrust of the strategy analysis has been to determine to what extent the use of other resources and technologies could reduce the demand for oil. Because of the critical importance of petroleum to the country's future economic development, such a reduction would have clear economic benefits, either in reducing the national oil import bill or in obtaining oil export revenues. Table 4.3-7 and Figure 4.3-11 summarize the energy demand balances that would result from the implementation of the various strategies discussed in the previous sections.

Figure 4.3-12 shows the projection of oil demand for the various strategies. The variation for the individual strategies between the highest level (Reference Case) and the lowest individual strategy (Increased Efficiency) is less than 10 percent. The last case presented incorporates changes to the Reference Case and applies a combination of all supply strategies analyzed. It results in a potential decrease of 96,000 barrels per day, or almost 28 percent.

The importance of the various strategies discussed goes beyond analysis of oil production in balance with oil demand. Solar energy, wind power, small scale hydro power, and biofuels have the potential of making significant local contributions to economic and social development in rural areas. If these technologies are to play an important role in Peru, a broad set of development and demonstration programs must be instituted.

Because of the large uncertainties surrounding the coal resource base, a fairly conservative estimate was made of the future role of coal. Coal can fulfill a unique need, as exemplified by its metallurgical uses. Should further examination of the extent and quality of Peru's coal resources show commercially exploitable deposits, coal could make a more significant contribution than that indicated here. That identification must be included as a high priority in future energy programs.

The case of increasing energy efficiency is special in that it is not perceived as an "option" but rather as an integral part of Peru's future energy development. Improvements in the combustion of noncommercial fuels in rural areas (ignored in the analysis of this strategy) can have a large impact on total firewood requirements. Pricing policies are central to any conservation efforts for commercial fuels; however, analysis of pricing policies was not performed in this assessment.

Peru's substantial energy base, particularly hydro power, suggests that intelligent integrated planning of energy and economic development can make a significant contribution to the country's economic future.

FIGURE 4.3-11 RESOURCE CONSUMPTION IN 2000 UNDER ALTERNATIVE STRATEGIES

FIG 4.3-12 PROJECTIONS OF OIL CONSUMPTION
REFERENCE CASE AND VARIOUS ENERGY STRATEGY IMPACTS

Table 4.3-7
Impact of Energy Strategies on Resource Requirements, 2000
(10^{15} Joules)

Resource	Reference Case	Increased Energy Efficiency	Impact	Increased Use of Renewables	Impact	Increased Use of Hydropower	Impact	Increased Use of Coal	Impact	Combined Strategies	Impact
Oil	772.5	694.8	-77.7	751.5	-21.0	718.7	-53.8	746.1	-26.4	552.2	-220.3
Natural Gas	29.0	29.0	--	29.0	--	29.0	--	29.0	--	29.0	--
Hydro*	297.0	303.7	+6.7	303.5	+6.5	368.3	+71.3	297.0	--	374.8	+77.8
Coal	100.1	100.1	--	100.1	--	100.1	--	126.5	+26.4	117.8	+17.7
Nuclear	--	--	--	--	--	--	--	--	--	--	--
Solar/Wind	--	--	--	1.6	+1.6	--	--	--	--	1.6	+1.6
Geothermal	--	--	--	3.2	+3.2	--	--	--	--	3.2	+3.2
Biomass/ Bagasse	11.5	11.5	--	11.5	--	11.5	--	11.5	--	11.5	--
Firewood/ Other	108.0	108.0	--	122.3	+14.3	108.0	--	108.0	--	197.9	+89.9
TOTAL Resource	1318.1	1247.1	-71.0	1322.7	+4.6	1335.6	+17.5	1318.1	0.0	1288.0	-30.1

*Includes Mini-Hydro

4.4 Financial Analysis of Strategies

The cumulative capital requirements (in January 1978 dollars) for the Reference Case and the five strategies examined are summarized in Table 4.4-8. The total capital requirements show very small variations, which is a reflection of : 1) the relatively small differences in the expansion schedule of supply facilities postulated for each of the strategies, vis-a-vis the Reference Case; 2) the fact that in some cases, part of the capital investment required to achieve the oil savings is omitted from the analysis (e.g., the improved end-use devices in the Increased Efficiency Strategy, or the comparatively more expensive coal-burning devices in the Increased Coal Strategy).

The largest share of cumulative capital costs in the Reference Case goes to the electric sector (about 60 percent), followed by oil exploration, production and distribution (about 38 percent). The remainder goes to production of natural gas and coal.

Total yearly outlays for the energy sector comprise the debt service on capital investment (including repayment of principal and interest), operation and maintenance costs, and costs of imported fuels - if any. Table 4.4.9 summarizes the estimated cumulative cash requirements for the period 1978-2000. These have been circulated based on an interest rate of 8.5 percent for the foreign debt portion of total capital requirements, and \$20 per barrel for oil imports. It also assumes a 15 year payback period for loans; thus, the cumulative cash requirements for the 1978 - 2000 period omit the portion of repayments due in the period between 2001 and 2015.

The largest impact on cash requirements appear in the cases where postulated oil production is sufficient to meet oil demand, reducing the import bill to zero. In these cases, the cost of the oil sector is based on producing just the amount needed to meet demand; in the cases where the possibility of oil export exists, production costs for this portion are omitted.

Table 4.4-8

Cumulative Capital Requirements, 1978-2000^a
(million dollars, Jan. 78)

Resource	Reference Case	Increased Efficiency	Increased Renewables	Increased Hydro	Increased Coal	Combined Strategy
Oil	\$ 5351	\$4907(-442)	\$5079(-272)	\$4936(-415)	\$5079(-272)	\$4149(-1202)
Gas	64	64(- 0-)	64(- 0-)	64(- 0-)	64(- 0-)	64(- 0-)
Coal	123	123(- 0-)	123(- 0-)	123(- 0-)	156(+ 43)	156(+ 43)
Electricity	8441	8619(+178)	8760(+319)	9200(+759)	8441(- 0-)	9551(+1110)
Hydro	5623	5764	5623(- 0-)	6524(+901)	5623(- 0-)	6524(+901)
Geothermal	-	-	47(+ 47)	-	-	47(+ 47)
Other	1445	1445(- 0-)	1445(- 0-)	1118(-327)	1445(- 0-)	1421(- 24)
Transmission and Distribution	1373	1110(+ 37)	1373(- 0-)	1558(+142)	1376(+ 3)	1558(+185)
Solar	-0-	-0-	85(+ 85)	-0-	-0-	85(+ 85)
TOTAL	13987	13714(-273)	13839(-148)	14324(+337)	13771(-210)	14002(+ 15)

^a Figures in parentheses denote differences with Reference Case; Source: Annex - 10

Table 4.4-9

Cumulative Cash Requirements, 1978-2000^a
(million dollars, Jan. 78)

	Reference Case	Increased Efficiency	Increased Renewables	Increased Hydro	Increased Coal	Combined Strategy
Debt Service ^b	\$ 7400	\$ 7400	\$ 7500	\$ 7600	\$ 7400	\$ 7600
Operation and Maintenance	5000	4900	5000	4900	5100	4900
Imported Oil ^c	<u>1700</u>	<u>0</u>	<u>1600</u>	<u>0</u>	<u>1300</u>	<u>0</u>
Total	14100	12300	14100	12400	13900	12500

^a Totals may not add due to rounding.

^b Includes scheduled repayments of principal - Foreign debt at 8.5% interest. Domestic debt at 0.0%.

^c Assumes oil price of \$20 per barrel.

Notes and References to Section 4

1. R. Revelle, "Energy Use in Rural India," Science, 192 (1976), 969-975.
2. A. Makhijani in collaboration with A. Poole, "Energy and Agriculture in the Third World", 1975, Cambridge, Mass.
3. United Nations Environment Program, "Review of the Impact of Production and Use of Energy on the Environment and the Role of UNEP," Report No. 75-40793, UNEP/GC/III/6/revision 1, 1975.
4. Renewable energy sources in part replace oil products directly, or replace oil-fire electricity, and in part provide energy to meet new demands in rural areas. Technologies that replace 1.95×10^{15} joules of electricity from oil are: geothermal (0.95×10^{15} joules of electricity), wood gasification (0.52×10^{15} joules) and wind and photovoltaics (0.47×10^{15} joules). In addition, wind and photovoltaics provide 0.49×10^{15} joules of electricity to meet new demands. Mini-hydro supplies an additional 1.38×10^{15} joules to meet new demands for electricity, indicated in Figure 4.3-1 as 1.87×10^{15} joules to a rural electrification sector. Solar water heaters provide $.063 \times 10^{15}$ joules of thermal energy, of which 0.57×10^{15} meet urban demands, and 0.06×10^{15} meet rural demands. This represents a replacement of oil to the residential sector of 0.42×10^{15} joules and a savings in electricity of 0.22×10^{15} joules. Charcoal is shown displacing 6.0×10^{15} joules of oil to the rural cooking sector, which added to 0.2×10^{15} joules from anaerobic digester totals 6.2×10^{15} joules of biomass resources replacing petroleum on a one to one basis. Finally, ethanol from sugar (i.e., alcohol) yields a savings in oil of 6.0×10^{15} in the transportation sector.
5. The modifications in energy flows from the increased efficiency strategy are indicated in a unique fashion in Figure 4.3-3 as straightforward decreases in consumption with respect to the Reference Case i.e., no alternative supply sources have to be shown substituting for this decrease. In industry, a savings of 15.1×10^{15} joules of petroleum is shown in the process heat demand category (see Table 4.3-4) that includes savings in mining and manufacturing due to improved practices. Reduced demand for electricity results in a decrease in petroleum for selfgeneration of 24.4×10^{15} joules, for a total petroleum savings in industry of 39.5×10^{15} joules (see Table 4.3-5). In the transportation sector, automobile savings of 3.0×10^{15} joules are obtained by an improvement of 5 percent in average fleet efficiency; a savings of 14.7×10^{15} joules in trucks is obtained from improved highway maintenance (7.7×10^{15} joules, see section 4.3.2.3 a), and fleet efficiency improvement of 5 percent (7.0×10^{15} joules). Bus consumption drops 13.0×10^{15} joules, due in part to electrified mass transit (which requires 2.0×10^{15} in additional electric generation), and in part to increased fleet efficiency. The

latter amounts to 2.7×10^{15} joules. Mass transit signifies savings of 6.0×10^{15} joules due to the shift in passenger miles, and an additional 4.3×10^{15} joules saved from decongestion (see section 4.3.2.3b). Air transport results in a savings of 5.2×10^{15} joules due to improvements in efficiency.

6. An increase in electric generation of 21.4×10^{15} joules by hydro-electric plants is obtained as follows: 2.0×10^{15} joules from electrified mass transit (substituting 10.3×10^{15} joules of petroleum consumption by buses, see 4.3.2.3b); 5.9×10^{15} joules from replacing 23.7×10^{15} joules of oil from selfgeneration in industry [$23.7 \times (0.25) \times (0.90) / (.88) = 5.9$], and lastly, 13.5×10^{15} joules of increased electricity generation due to technology changes in the mining sector that yield a savings of 19.8×10^{15} joules (assuming a boiler efficiency of 60 percent, the work provided by 19.8×10^{15} joules of petroleum is 11.9×10^{15} joules; taking into account a transmission and distribution efficiency of 88 percent, it yields an electric generation requirement of 13.5×10^{15} joules).
7. The coal use strategy shows substitutions of petroleum uses in industry by coal in four industries: 4.0×10^{15} joules in the mining sector, 2.0×10^{15} joules in iron and steel, and 15.7×10^{15} joules in the cement and chemical industries (see section 4.3.4.2). In addition, a 4.7×10^{15} joules are replaced in fuels to selfgeneration (see section 4.3.4.2).
8. The modifications in flows for the combined strategies are obtained from Table 4.3-6. Figure 4.3-9 incorporates these oil savings as follows: a total of 27.3×10^{15} joules of petroleum is saved in the residential sector from substitution by charcoal (6.0×10^{15} joules) solar (0.6×10^{15} joules), and by introducing the alternative projections (20.7×10^{15} joules). A total decrease of 95.3×10^{15} joules in transportation demand is obtained from electrified mass transit (10.3×10^{15} joules), from the alternative projection (63.0×10^{15} joules), and from efficiency improvements (22.0×10^{15} joules). The total petroleum savings in this sector are increased to 101.3×10^{15} joules by substitution of 6.0×10^{15} joules with alcohol. In electric generation, a savings of 7.8×10^{15} joules of oil is obtained by substitution of 1.95×10^{15} joules of electricity generation with geothermal (0.96×10^{15} joules), wood gasification (0.52×10^{15} joules) and wind and photovoltaics (0.47×10^{15} joules). Rural electrification is introduced as an added demand of 1.87×10^{15} joules from mini-hydro (1.38×10^{15} joules), wind, and photovoltaics (0.49×10^{15} joules). In the industrial sector, increased electrification yields a savings of 19.8×10^{15} joules of oil to mining, and a combination of increased use of coal (17.7×10^{15} joules) and increased efficiency (13.3×10^{15} joules) decreases oil demand for process heat by 31.0×10^{15} joules. This results in an additional use of coal of 17.7×10^{15} joules. Use of oil for self-

generation decreases by a total of 26.5×10^{15} joules, of which 23.7×10^{15} is due by substitution with hydro and 2.80×10^{15} from decreased utilization due to efficiency improvements. The total increase in conventional hydro generation is due to mass transit (2.0×10^{15} joules), replacement of oil in selfgeneration (5.9×10^{15} joules) and use of more electric intensive processes in the mining sector (13.5×10^{15} joules).

5.0 OBSERVATIONS AND NEXT STEPS

Much of the value of the analysis in the previous sections lies not in the numerical results, but in the number of insights or perspectives that it provides into Peru's energy future and its energy planning. Since this assessment is a preliminary technical analysis, rather than a policy study, these insights are presented as observations rather than as recommendations or findings. This section provides observations on the following topics:

- o Limits on the ability to project Peru's energy future;
- o Future demand for energy in Peru;
- o Energy resources in Peru;
- o Energy costs and financing capabilities;
- o Manpower capabilities; and
- o Energy system planning and analysis considerations.

Where it is appropriate, observations are included about near-term actions that appear to be needed in specific areas that would permit the Government of Peru to build promptly upon the results of the assessment. More detailed information on these "next steps" is provided in the annexes that supply the specialist's contributions to the analysis.

5.1 Limits on Projections

There are many factors that could cause Peru's energy future to differ from the projections in the reference case of this assessment or the alternative futures that are presented in the strategies. Other changes could stem from such factors as:

- o the preparation of long-range economic, development, and energy system plans that are more cohesive and consistently prepared;
- o prospective changes in the policies and programs of the Government of Peru with respect to population migration and industrial expansion that, in turn, could materially affect the planned expansions and improvements of Peru's transportation system and its capability to use more energy-efficient transportation modes;

- o the pace at which recovery from the recent period of economic stagnation will be attained and the continuing ability to maintain the recently instituted monetary reforms;
- o the extent to which the energy consumed by Peru's populace will be subsidized, and related price/demand impacts that could result from the elimination of fuel cost subsidies;
- o the extent to which the rural population in Peru will shift from the use of noncommercial fuels to commercial fuels to meet basic energy needs;
- o the uncertainty that adequate additional oil reserves will be found to meet Peru's future oil production goals, and the extent to which additional oil production and transportation facilities can be constructed in a timely fashion; and
- o whether Peru's very large hydroelectric resources can be developed in an economical fashion.

These uncertainties and limitations notwithstanding, this assessment has identified the major energy demand and supply options that are available to Peru. In addition, it has also established their relative significance in Peru's energy future.

5.2 Energy Demand

The demand for commercial energy in Peru is projected to increase by a factor of three to four times between 1976 and the year 2000, while the use of noncommercial energy forms (firewood, animal dung, crop residues) will remain relatively constant or may even decline slightly as rural households increase their use of commercial fuels. Commercial energy demand is, and will continue to be, dominated by the transportation and industry sectors, each of which now consumes approximately 35% of commercial energy in Peru. Energy demand initiatives in the industry sector can focus upon substitutions of electricity and coal for the use of oil, as well as more efficient use of energy. Since fuel substitution opportunities are limited, energy initiatives in the transportation sector need to focus on reductions in transport activity levels or greater use of more energy-efficient transportation modes to directly reduce the demand for oil.

Electricity will provide an increasing proportion of Peru's future energy needs; the ratio of electricity consumption to total energy consumption is anticipated to increase from about 8% in 1976 to 12% in 2000. This increasing role of electricity is consistent with the need to make greater use of Peru's hydroelectric potential and is generally in line with the experience of other countries at a stage of development similar to

that in Peru. However, it should be recognized that electricity is a capital-intensive energy conversion and delivery system. As a result, any increased role for electricity will involve greater financing requirements and potentially greater amounts of foreign exchange for imported equipment and labor.

Opinions differ as to the extent to which commercial energy will substitute for the use of noncommercial fuels in rural households. The reference case in the assessment assumes this substitution will occur beyond 1985 at such levels that consumption of noncommercial fuels will decline significantly. On the other hand, a recent UNDP survey projects a continued increase in noncommercial fuels' use through 2000. Although either projection could be significant in terms of the effect on both the demand for specific fuels (e.g., kerosene) and the achievement of rural development goals, the impact on total commercial energy demand in the year 2000 would probably not be greater than a few percent.

5.3 Energy Resource and Supply Capability

Oil

Although oil use will decline from more than 72% of Peru's commercial energy consumption in 1976 to about 64% by the year 2000, oil will continue to dominate Peru's energy needs and supply capability. The availability of indigenous oil reserves at the necessary levels is not assured. Moreover, an oil production capacity of 318,000 barrels per day is optimistically estimated to be achievable by the year 2000, while demand is similarly projected to be approximately 345,000 barrels per day. If the reference case supply/demand balance is a reasonable projection, Peru would need to import oil at levels that are almost 10% of its oil requirements at that time.

However, an examination of alternative energy planning strategies that include measures to reduce the demand for oil and/or to substitute other energy forms indicates that the need to import oil could be avoided if such measures were pursued vigorously.

Moreover, current Peruvian oil exploration incentive arrangements will present an apparently anomalous situation. That is, a significant portion of Peru's future domestic oil demand will be met by oil purchased at world oil market prices, even though it will have been produced in Peru. Unless Peru improves its independent capability, either to find and produce oil or to reduce the risk associated with the exploration and development of new oil fields by private oil companies, similar incentive arrangements will continue to be needed. In view of this, Peru should examine measures to improve its capability to assess independently the prospects for oil, particularly in the Amazon jungle regions where the better potential for new oil fields appears to exist.

Natural Gas

It does not appear at this time that natural gas will be an important factor in Peru's energy future. Proven reserves are small, and the potential resources are uncertain, since they depend in large measure on continuing oil exploration efforts in the Amazon jungle region. Until an improved view of gas reserves becomes available, little effort appears to be warranted in planning for the increased use of natural gas.

Coal

Peru's coal resources could supply an increasing proportion of Peru's commercial energy needs. A significant portion of the increased use of coal could be in its use as coke for the iron and steel industry, and this would reduce the current and projected need to import coke. The economic motivation to use coal for other industrial requirements should be significantly strengthened by continuation of the recently implemented monetary reforms. Although some increased use of steam coal for electric power generation is planned, further increases in the use of coal for this purpose will depend upon the availability of local coals and the relative economics of hydro-electric vs. coal-fired electric generation projects. In this light, it is important that Peru expeditiously determine the magnitude and quality of its coal reserves as a basis for fully considering the increased use of coal. Peru should also initiate an assessment of water availability for coal processing and begin to establish the infrastructure necessary to support increased production and use of coal.

Hydroelectricity

Hydroelectric energy will make an increasing contribution to Peru's energy supply capability during the period to 2000 and is likely to be a crucial element in Peru's long term development and energy planning. Peruvian energy planners have clearly recognized the potential of hydro-electricity, but it is less clear that other Peruvian planners and policy makers recognize its multipurpose development role.

Peru's hydroelectric potential is of two types: (1) large-scale dams that would provide large blocks of energy to a central electric grid that would serve major demand centers; and (2) mini-hydro units that would provide smaller quantities of power to rural villages and remote mining or other industrial facilities.

Although the hydroelectric potential of the east slope of the Andes is very large, the economics of developing it must be based upon the evaluation of specific projects, including consideration of transmission of the generated power to the major demand centers. The planned integration of Peru's numerous isolated transmission grids into three major interconnected grids will significantly enhance the ability to exploit this hydroelectric potential effectively.

The contribution of mini-hydro facilities to supporting the energy needs and general development of rural communities has already been demonstrated. Accordingly, the Government of Peru should aggressively pursue its plans for increasing the number of mini-hydro installations. While much of the energy produced by these facilities will satisfy newly created demand for energy and thus not contribute directly to meeting the energy demand of major load centers, it may contribute significantly to reducing the rural-to-urban migration of the population.

The contribution that hydroelectric facilities can make to the attainment of other objectives (water resource development, flood control, rural development, etc.) makes it essential that hydroelectric facility planning be closely integrated with the planning of those other activities.

On this basis, early actions in planning increased use of hydroelectricity should be directed at:

- o site-specific evaluations of the potential economics of large hydroelectric projects and their potential role in Peru's development planning;
- o improved coordination of these evaluations with the programs in other ministries that could be affected by such projects, including formulation of policies for sharing the cost of these large projects; and
- o expansion of programs for installation of mini-hydro facilities to facilitate the development of rural areas that will not be able to obtain electric energy economically from the electric grid.

Solar and Wind Energy

Systems that directly convert solar radiation to other useful energy forms are not expected to make a major contribution to meeting Peru's commercial energy needs before the year 2000. Specific solar applications could contribute to the economic and social development of rural communities in some regions of Peru and could provide an economic energy supply to remote industrial or mining facilities at which the cost of energy from alternative systems is now high. Wind energy systems might also be applied effectively in these situations, although insufficient data on the wind conditions in Peru are available to assess this potential at this time.

To realize the potential contributions of solar energy, Peru should initiate programs that would (a) collect better data on solar and wind conditions; and (b) demonstrate solar and wind systems in Peru. This will permit the comparative evaluation of the economics of solar and wind systems and support planning for the increased use of such energy systems.

Biomass Energy Systems

The extent to which the traditional uses of biomass (e.g., rural cooking) will continue appears to depend primarily upon the availability of commercial energy (kerosene or electricity) at affordable prices in rural communities. As noted above, opinions differ about the pace at which this substitution will proceed; however, its effect will be observed more in terms of changes in the demand for specific fuels than in changes in the overall demand for commercial energy forms.

A potential exists for large-scale use of new, non-traditional use of the biomass resources in the forests on the eastern slopes of the Andes or through the development and use of cultivated biomass products near these areas. Technologies for such uses are currently available. However, the location of this potential resource in a difficult environment, distant from Peru's major energy demand centers, poses difficult economic and developmental challenges to the prospective use of biomass as a significant commercial energy resource. In addition, the possible adverse environmental impact of large-scale forest operations could be crucial to decisions to attempt to use this resource.

Peru's programs to reforest areas on the western slopes must consider a possible expanded role for biomass energy. Any evaluation of the use of biomass resources for energy would need to include participation of those ministries and programs which are directing their efforts toward the development of these regions.

To this end, future energy planning would clearly benefit from a better evaluation of: (a) the current and projected use of biomass resources in rural households, including the prospect that improved efficiency cooking stoves could extend the usefulness of this energy resource; (b) measures to achieve an orderly transition from the traditional use of noncommercial fuels to commercial fuels, focussing initially on areas of current or potential deforestation; and (c) the effective use of wood, bagasse, and other biomass wastes at existing and planned wood and food processing facilities. Any further examination of the potential economic and development feasibility of large-scale exploitation of the east slope and jungle forests as an energy resource should be carried out as part of Peru's long-term broader-scope regional development plans.

Geothermal

Although certain general geologic characteristics appear favorable, the potential of commercially exploitable geothermal resources is uncertain. Until clearer indications are available, it appears that geothermal energy cannot be expected to make a significant contribution to Peru's future energy supply capability.

Nuclear Power

Peru's intentions to make a decision on the use of nuclear power systems sometime before 1995 appear to be appropriate. Those plans also call for that decision to consider carefully the comparative economic prospects at that time for expanded development of Peru's hydroelectric potential. That evaluation should also consider the technical, managerial, and institutional complexities that are involved in the widespread use of nuclear systems.

5.4 Energy Cost and Financing

As long as it is necessary for Peru to offer attractive incentive arrangements for oil exploration and development, a significant portion of the oil consumed in Peru will be acquired at prevailing world market prices. Moreover, as noted earlier, the economics of Peru's potentially vast hydroelectric sources require further evaluation, and major capital investments will be needed for both new generation and transmission facilities in any event. As a result, consumers of energy in Peru should expect cost increases. This could be exacerbated by strict adherence to recent monetary reforms, which could result in most of these energy cost increases flowing through to the end-users of the energy. However, the effects that increased energy costs would have on consumption cannot be accurately ascertained at this time.

On the other hand, Peru has the opportunity to minimize the full extent of these prospective cost increases through effective and properly timed exploitation of its potential indigenous resources. Although neither was specifically analyzed in this assessment, the prospect of both near-term cost increases to the end-user, and the potential for longer-term energy cost stabilization should be kept in mind in Peru's economic and general development planning, as well as its energy sector planning.

The capital investment requirements of the energy supply sector will increase significantly. However, if Peru achieves the economic growth goals that were assumed for this assessment, the ratio of energy supply sector investments to total investment should not change significantly from historic ratios. As a result, Peru should be able to finance its energy supply investments, although there may be short-term distortions or constraints that stem from the recent economic downturn. In addition, measures to improve domestic savings could be crucial to Peru's ability to support such investments.

Peru should focus its external and internal financing capability upon those projects which are of high priority in Peru's overall development plans. Comprehensive energy planning can contribute to this decision-making process and should be directed to assure that anticipated revenues from energy facilities are adequate to cover the debt service on invested foreign and domestic capital.

5.5 Manpower Capabilities

The availability of management, technical, and administrative professionals and skilled craftsmen will become a matter of growing concern as Peru's economy and the energy sector grow. Peru is meeting a substantial portion of the current manpower needs of the energy sector with domestic sources. If this is to continue, specialized manpower training programs should be planned and implemented as an integral part of the energy sector programs, and as well as to supplement Peru's basic education and training activities under the Education Reform Act of 1972. These energy sector programs should be directed at (a) improving the experience level of current and incoming personnel in the technologies and project management requirements of large energy projects; (b) providing personnel that are competent in comprehensive energy planning and in the critical evaluation of alternative projects; (c) providing personnel that are experienced in the design and application of quality assurance processes during facility design, construction, and operations and maintenance; and (d) providing increasing numbers of personnel trained in the specialized skills of planning, siting, managing, designing, constructing, and operating complex energy facilities. Accomplishing this will require a greater degree of coordination by energy sector officials and planners with those responsible for general manpower development and training.

5.6 Energy System Planning and Analysis

This cooperative assessment has attempted to demonstrate the methods and benefits of conducting a comprehensive energy resource and technology assessment to the Government of Peru. Any continuation of such comprehensive energy planning activities should consider the following observations that are based on the assessment process.

Although this cooperative assessment was done on a national basis, it attempts to take into account the more significant regional differences that exist in Peru and their major impacts on energy planning at the national level. However, because the three major regions of Peru and their sub-regions are so diverse, more detailed assessments of regional energy needs, uses, and resources will be necessary to provide an improved information base for Peruvian policy makers and planners. Such regional assessments could support current policies that are directed toward decentralization of economic activity, since such detailed regional assessments would provide improved projections of local energy needs and resources. In addition, regional assessments would provide an opportunity for expanded training and experience in the methodology of comprehensive energy planning and analysis.

The demand for energy is intimately connected with the economic growth objectives of a country. This is particularly true for Peru, since so much of the demand for energy is established by the industry and transportation sectors. Accordingly, the effect upon energy demand of different growth rates in achieving the objectives in these sectors warrants more thorough examination. Also, alternative ways exist that will achieve the same goals with different quantities or different types of energy. This can involve significant changes in the industrial sector, either in the types of industrial activities or in different processes that produce the same end-product. The energy demands of the transportation sector offer less flexibility in the types of fuels needed. However, its activity levels can be changed significantly by policy and program alternatives that are available to the government. In addition, transportation activity levels are usually closely related to industrial planning goals. As a consequence, future national energy plans need to build upon current planning for the industrial and transportation sectors.

Energy forecasts benefit immeasurably from good data on current energy consumption patterns and supply capabilities. Accordingly, a first step in improving the capability of the Government of Peru to conduct comprehensive energy planning and analysis is to establish and implement improved procedures and processes for the collection, storage, retrieval, and manipulation of energy data. Such a data system should cover all aspects of energy resources, production, conversion, delivery and end-use.

Although current efforts show promise, the interrelationship between energy planning and economic planning at the national and sectoral levels needs to be even more fully emphasized. For example, some energy facilities such as dams are multipurpose, in that they provide both energy and water, while others (e.g., coal processing plants) are large water consumers. Construction and operation of energy production and delivery systems are major elements in the economic activity of the nation and

place heavy demands upon the manpower, equipment, and service capabilities of the country. Such undertakings can also involve substantial foreign trade requirements. The availability and cost of energy has a critical effect not only on the economic feasibility of various industrial and transport alternatives, but also on programs for local development of rural areas. Accordingly, it is essential that energy planning activities be conducted in close and continuous coordination with those ministries of the government and elements of the private sector that are responsible for these other development activities.

The proper kinds of institutional arrangements can enhance the coordination and development of well-founded national energy plans. However, more important than a particular organizational structure are the following principles:

- o one organizational entity should have primary responsibility and authority for integrated national energy planning;
- o measures should be taken to insure the active participation of other ministries, regional agencies, or organizations that are responsible for planning in other sectors of the economy, or that will be significantly affected by the energy plans that are prepared for implementation;
- o the ministries responsible for economic development, finance, and manpower training must actively participate in the preparation of national energy plans;
- o the effects of existing regulations and the prospective need for new regulations, and/or regulatory authorities or criteria, should be incorporated at an early stage in the planning process; and
- o a process should be established for reviews by policy making personnel of all national or regional plans and major program or project evaluations, in order to assure that decisions on alternatives are well based and carry with them both high-level support and adequate priority to ensure effective implementation.

APPENDIX A
LISTING OF PERUVIAN ORGANIZATIONS
CONSULTED BY THE U.S. TEAM

LIST OF PERUVIAN ORGANIZATIONSCONSULTED BY U.S. TEAMORGANIZATION

Andean Pact

Backus y Johnson

BELCO

BID (Interamerican Development Bank)
(Banco Interamericano de Desarrollo)

CECOAAP

CEMENTO SUR S.A.

CENIP

CEPD

COFIDE

COMPANIA DE MINAS BUENAVENTURA
(Buenaventura Mine Company)

COMPANIA NACIONAL DE CERVEZA S.A.

CONUP

COSAPI S.A.

ELECTROLIMA

ELECTROPERU

ELECTROPERU-TARAPOTO

FAO (Food & Agriculture Organization)

Fertisa

HIERROPERU

IGP (Peruvian Institute of Geophysics)

INCITEMI (Scientific & Technologic
Mining Institute) (Instituto
Cientifico y Tecnologico Minero)

LIST OF PERUVIAN ORGANIZATIONS (continued)

CONSULTED BY U.S. TEAM

I

ORGANIZATION

INE (National Statistical Institute)
(Instituto Nacional de Estadisticas)

Ingenieros Electricas

INGEOMIN (Geology and Mining Institute)
(Instituto de Geologia y Minería)

INIE (Institute of Electrical
Investigations & Electrical Engineer
Service) (Instituto de Investigaciones
Energeticas y Servicios de Ingenieros
Electrical)

INP (National Planning Institute)
(Instituto Nacional de Planificacion)

International Executive Service Corp.

IPEN (Peruvian Institute of Nuclear
Energy) (Instituto Peruano de
Energia Nuclear)

ITINTEC (Institute of Industrial
Technology Investigation & Technical
Specification) (Instituto de
Investigacion Tecnologica Industrial
y de Normas Tecnicas)

LAHMEYER INTERNATIONAL CONSULTING ENG.

METINSA

MINEROPERU AND CENTROMIN (Peruvian
Minery)

MINISTRY OF AGRICULTURE AND FOOD

MINISTRY OF AGRICULTURE-IQUITOS

MINISTRY OF AGRICULTURE-TARAPOTO

MINISTRY OF ECONOMY AND FINANCE

MINISTRY OF EDUCATION

LIST OF PERUVIAN ORGANIZATIONS (continued)CONSULTED BY U.S. TEAMORGANIZATION

MINISTRY OF ENERGY AND MINES

MINISTRY OF HOUSING AND CONSTRUCTION

MINISTRY OF INDUSTRY AND TOURISM

MINISTRY OF LABOR

MINISTRY OF TRANSPORT AND COMMUNICATIONS

MOTLIMA CONSULTORES S.A.

MULTISECTORIAL COMMISSION OF NATIONAL
PLAN OF ORDER OF HYDRAULIC SOURCES

OCCIDENTAL PETROELUM CORPORATION

ONERN (National Office of Evaluation of
Natural Resources) (Oficina Nacional
de Evaluacion de Recursos Naturales)

Parker Drilling Company

PERUVIAN EMBASSY

PESCAPERU

PETROPERU (Petroleum of Peru)
(Petroleos del Peru)

PIAZZA AND VALDEZ ENGINEERS

QUIMICA DEL PACIFICO

SECIGRA (Graduates Civil Service)
(Servicio Civil de Graduandos)

SENAMHI (National Service of Hydrology
and Meteorology) (Servicio Nacional
de Meteorologia e Hydrologia)

SIDERPERU (Peruvian Siderurgy)
(Siderurgica Peruana)

LIST OF PERUVIAN ORGANIZATIONS (continued)

CONSULTED BY U.S. TEAM

ORGANIZATION

SINAMOS (National System of Social
Mobilization Support) (Sistema
Nacional de Apoyo a la Mobilizacion
Social)

SOC. PARAMONGA LTDA. S.A.

SUGARMILL CASA GRANDE--TRUJILLO

UNDP (United Nations Development
Program)

UNIVERSITY OF CUZCO

UNIVERSITY NACIONAL AGRARIA LA MOLINA

UNIVERSITY NACIONAL MAYOR DE SAN MARCOS

UNIVERSITY TECNICA DE CAJAMARCA

WATER COMPANIES

WORLD BANK

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APPENDIX B.1

ENERGY RESOURCES AND PRODUCTION

APPENDIX B.1 - ENERGY RESOURCES AND PRODUCTION

The following sections discuss each of Peru's energy resources along with past and present trends in their production. For convenience the resources have been divided into three categories: (1) fossil fuels; (2) nuclear fuels; and (3) renewable resources.

1.0 Fossil fuels1.1 Oil and gas:

Peru's measured oil reserves (estimated at 560 million barrels) are distributed as follows: 380 million barrels in the Amazon region, 120 million barrels in the onshore part of the Talara basin of northwestern Peru, and 60 million barrels in the offshore part of the Talara basin. Additional identified oil reserves include 160 million barrels in the indicated reserves category that can be produced from the onshore part of the Talara basin by secondary recovery methods, and 95 million barrels in the inferred reserve category. These reserve estimates are summarized in Table B.1-1, and the definitions of terms are provided below.

Table B.1-1

Petroleum Reserves in Peru

Reserve Category	Reserves, Barrels x 10 ⁶
Measured reserves	560
Indicated reserves	160
Inferred reserves	<u>95</u>
Total identified reserves	815

Source: Communication from Rafael Antesana, Planning Manager, Petroleos del Peru.

Definitions of Terms Applied to Oil and Gas Resource Appraisal

Measured reserves. That part of the identified resource that can be economically extracted using existing technology and whose amount is estimated from geologic evidence supported directly by engineering measurements. In this report, they are considered to be equivalent

to proved reserves, as defined by the American Petroleum Institute (API) and the American Gas Association.

Indicated reserves. Reserves that include additional recoveries in known reservoirs (in excess of the measured reserves), which engineering knowledge and judgment indicate would become economically available by application of fluid injection, whether or not such a program is currently installed. In this study, indicated reserves are equivalent to API's indicated additional reserves.

Inferred reserves. Reserves in addition to demonstrated reserves, eventually to be added to known fields through extensions, revisions, and new pays.

Sub-economic resources. Identified and undiscovered resources that are not presently recoverable because of technological and economic factors, but which may be recoverable in the future.

Undiscovered recoverable resources. Those economic resources, as yet undiscovered, which are estimated to exist in favorable geologic settings.

A somewhat higher estimate of oil reserves has been made by USGS specialists who participated in the assessment. According to their estimates, the total of Peru's measured, indicated, and inferred oil reserves is 1,095 million barrels, distributed as follows:

Table B.1-2

Petroleum Reserves in Peru

Category	Reserves, 10 ⁶ bbl	
Measured reserves	565	
Amazon region		385
Talara onshore		120
Talara offshore		60
Indicated reserves (secondary recovery, Talara)	500	
Inferred reserves	30	
TOTAL	1,095	

Source: USGS, Ref.. B.1-1

In the undiscovered recoverable resources category, estimates vary widely. For example, early authors had estimated the undiscovered oil resources of Peru to be about 50 billion barrels. However, on the basis of more recent exploration, officials of PetroPeru have agreed

that undiscovered oil resources probably amount to approximately 26 billion barrels.

However, the objective of this report is to arrive at a basis for estimating possible oil production for the years 1978-1985, as well as and the year 2000, rather than to estimate Peru's potential hydrocarbon reserves. For this purpose, we categorize significant undiscovered resources as those that possibly could be exploited within the time frame covered by this study. We eliminate from consideration those undiscovered resources that are believed to exist both in water depths beyond the continental shelf and in stratigraphic traps in the Amazon region. The technology for producing hydrocarbons seaward of the continental shelf is not fully developed and will probably not be employed for another 10 years. The search for stratigraphic traps in the Amazon basins must follow extensive accumulation of more subsurface information from drilling and be aided by seismic stratigraphic studies. With these considerations in mind, USGS specialists discussed the undiscovered resources of the coastal basins with scientists of PetroPeru, Belco, Occidental, and Geopet (a Peruvian consulting company based in Lima, Peru).

Estimates of the undiscovered recoverable oil resources of Peru are listed, by basin, in Table B.1-3. For coastal basins, high and low estimates are shown. These values bracket the estimates made by scientists with whom discussions were held. The estimates of undiscovered resources of the Amazon basins were made on the basis of areal extent. That is, the total oil resources of Blocks 1A, 1B, and 8 (the present producing areas of the Amazon region shown in figure B.1-1) were estimated to be 560 million barrels. (based on areal extent). These resulting amounts of oil per block were then reduced by a "richness factor." The richness factors, generated by the USGS specialists, were 0.75, 0.50, and 0.50 for the Marañon, Ucayali, and Madre de Dios basins, respectively. The richness, or reducing factors, are less than 1.00 because southward from the main producing areas of the Amazon region (Blocks 1A, 1B, and 8), structures of the type from which oil is currently being produced are few, and the organic content of potential source rocks is reduced. It should be noted that oil production to date from Blocks 1A, 1B, and 8 has been limited to structural traps located by standard seismic methods. It has been assumed, therefore, that estimates of undiscovered oil resources in the remaining areas of the Amazon basins include only those resources contained in structural traps that can be located by standard seismic methods (i.e., the estimates do not include potential resources that could be contained in stratigraphic traps).

Table B.1-3

Estimates of Peru's Undiscovered Recoverable
Oil Resources, Listed by Basin

Basin	Oil (Millions barrells)
Progreso	150-350
Talara (onshore)	50-500
Talara (offshore)	150-200
Sechura	50-100
Salaverry	150-500
Pisco	20-100
Maranon	880
Ucayali	330
Madre de Dios	280
TOTAL	2,060-3,240

Note: Estimates for the Amazon basins (Maranon, Ucayali, and Madre de Dios) do not include potential resources that may exist in stratigraphic traps. Estimates for the remaining basins do not include potential resources believed to exist in water depths beyond the continental shelf.

Source: Ref. B.1-1

Based on information available to date, Peru's reserves of natural gas are small. PetroPeru estimates place the measured gas reserves of the Talara basin at one trillion cubic feet. But, according to USGS specialists, the complexity of the area makes this estimate highly uncertain. Another gas field, Aquaytia, in the Ucayali basin is estimated by PetroPeru to have sub-economic resources of 318 billion cubic feet.

Estimates of undiscovered gas resources are given in Table B.1-4. Gas resources are estimated to range between 1.3 and 11.5 trillion cubic feet.

Oil Bearing Areas of Peru

FIG B.1-1

Table B.1-4

Distribution of Estimated Undiscovered Gas Resources

<u>Basin</u>	<u>Gas</u> Billions of Cu. Ft.
Progreso	200-500
Talara (onshore)	65-650
Talara (offshore)	185-260
Sechura	100-500
Salaverry	150-500
Pisco	20-100
Maranon	320-5,475
Ucayali	120-1,825
Madre de Dios	102-1,643
TOTAL	1,262-11,453

Source: Ref. B.1-1

Historical crude oil imports, exports, and production are shown in Figure B.1-2. Domestic crude oil production increased from 62,000 barrels per day in 1965 to 91,000 barrels per day in 1977. Despite this increase, Peru shifted from being a net oil exporting country to a net oil importer in the 1960s. By mid-1978, production again exceeded consumption and had attained a level of 163,100 barrels per day. Much of the increase came from the Amazon jungle region and was available for refinery and export through completion of the trans-Andean pipeline in 1977, and the northern branch pipeline in February 1978. The distribution of production between companies and regions for mid-1978 is shown in the Table B.1-5 below.

Table B.1-5

Petroleum Production, Mid-1978

<u>Company/Region</u>	<u>Production, bpd</u>
PetroPeru ^a	63,400
Jungle	31,700
Coast	31,200
Secondary Recovery	500
Occidental Petroleum ^b	70,800
Belco ^b	28,900
TOTAL	163,100

^a Petroleos del Peru, the Peruvian national petroleum company.

^b U.S. company.

FIG B.1-2 CRUDE OIL PRODUCTION, IMPORTS, AND EXPORTS

Under the terms of the production-sharing contract that Peru has with Occidental and Belco, half of their production is available to PetroPeru, while the other half is retained by the companies. Thus, as of mid-1978, the total volume of crude available to meet Peru's domestic demand is estimated to be 113,000 barrels per day. Additional supplies must be purchased at international market prices.

There are five major refineries in Peru currently in operation (all managed by PetroPeru). With the expansion of the La Pampilla refinery by a new 65,000 barrels per day crude distillation unit in 1977, the total crude refining capacity now amounts to 180,300 barrels per day. This capacity is large enough to handle the aggregate demand for products until 1985, although shortfalls (and surpluses) in individual products could well occur. The following table shows the five refineries and their capacities, plus a single refinery that is presently shut down.

Table B.1-6
Crude Oil Refining Capacity and Processing

Refineries	Capacity (bbl/day) ^a	Crude Processed (10 ³ bbl) ^b
Talara	65,000	25,564
La Pampilla	102,000	12,139
Conchan ^c	8,000	2,772
Marsella	1,400	
Iquitos	1,400	380
Pucallpa	<u>2,500</u>	<u>656</u>
Total	180,300	41,511

^a in 1977, Source: B. Tunnah, Annex 2.

^b in 1976, Source: U.S. Embassy, Lima, "Annual Petroleum Report", May 16, 1978.

^c currently shut down.

In 1976, among the various refined products, residual oil accounted for 31 percent of the total refinery output, followed by gasoline (29 percent), diesel oil (18 percent), and kerosene (12 percent).

In comparison with oil, Peru's natural gas production is of minor importance. Almost all of the natural gas produced is associated gas from the oil fields of the northwestern part of the country. Production amounted to 71.6 billion cubic feet in 1976 and increased slightly to 72.8 billion cubic feet in 1977.

1.2 Coal:

Coal deposits are reported to exist in 18 of Peru's 24 departments; they range in age from upper Jurassic to upper Tertiary and include coal ranging in rank from lignite to anthracite. At most localities, particularly in departments south of the Department of Huancavelica, the deposits are generally less than a meter thick, are of limited areal extent, and have little or no economic value. However, in central and northern Peru, coal beds with thicknesses greater than 2 meters are reported at numerous localities, some of which are either sites of formerly active mines or are in areas of active exploration.⁴

Coal found in rocks of upper Jurassic and lower Cretaceous ages has the greatest potential as a future source of energy. For the most part, such coal occurs in areas of rugged terrain at altitudes from above 2,000 meters to as high as 4,600 meters. Although many coal deposits are accessible by railroad and road, others can be reached only by foot or on horseback.

At present, none of Peru's coal resources is being exploited. In 1971, the Cerro de Pasco Corporation (now CentrominPeru) ceased exploitation of its Goyllarisquize mine, which had been in operation since 1908. This mine produced between 33,000 and 47,000 tons of bituminous coal annually in the 1965-70 period. Three small companies in the Santa Valley produced coal for export to Argentina from 1943 to 1965. According to official statistics, the last year in which coal was mined in Peru 1973, when a small amount of anthracite (12,000 metric tons) was produced in La Libertad Department. (Unofficial sources estimate that about 30,000 metric tons were produced that year.) Until 1973, there was no domestic market for coal because government subsidies made oil products more attractive. The rise in oil prices may make the use of Peru's coal resources competitive again.

Rank and Quality of Coal

Jurassic and Cretaceous coal range from sub-bituminous to anthracite, but in approximately two-thirds of the areas where coal occurs, it is reported to be anthracite. Based on a limited number of analyses from widely separated localities, this anthracite coal has a low ash and

low-to-moderate sulfur content, and heat values that range from 25×10^6 to 31×10^6 joules per kilogram. The ash content of sub-bituminous and bituminous coal from central Peru (where most of these types occur) is highly variable, ranging from 7 percent to as high as 41 percent. Analyses of the sub-bituminous coal from three thin beds (0.20 to 0.40 meters thick) in the Jatunhuasi area of the Pasco Department indicate 6 to 20 percent ash, 40 to 60 percent fixed carbon, and 0.6 to 2.0 percent sulfur. Heating values range from 21×10^6 to 29×10^6 joules/kg. Much of the bituminous coal forms low strength coke suitable for lead smelting furnaces, but not suited for the blast furnaces of steel mills, unless mixed with strong coking coal from other sources.

Reserves

According to standards adopted by the U.S. Geological Survey, measured reserves include coal within a one-fourth mile (0.4 kilometer) radius of a point at which the thickness of the coal bed has been accurately measured. Indicated reserves include coal within an area that extends one-half mile (0.8 kilometer) beyond the area of measured reserves, and inferred reserves include coal that extends 6 miles (9.0 kilometers) beyond the limit of indicated reserves providing geologic evidence indicates the persistence of coal beds. Thus, indicated and inferred reserves are a consequence of measured reserves.

Measured, indicated, and inferred reserves (more commonly reported as proven, probable, and possible reserves) are given in Peruvian reports, mostly unpublished, on areas of former mine sites or on areas that are currently under investigation. However, no attempt has been made to classify reserves on a nationwide basis according to internationally accepted procedures.

A reserve estimate of 1,060 million tons of coal for Peru has been given by one investigator. Of the 1,060 million tons, 142 million tons are classified as "measured" and "estimated". Unfortunately, the data on which these estimates are based are not provided by Peruvian sources, and thus, the figures cannot be interpreted as to their significance in terms of economically recoverable coal.

Areas of Production Potential

Although little coal is currently produced, four coal fields appear to hold potential as sources of fuel and coking coal. These include Alto Chicama and Santa Valley in northern Peru, and Oyon-Gazuna and Jatunhuasi in the central part of the country. Alto Chicama reserves are tabulated in Table B.1-7. Those of the other fields are considerably smaller.

Table B.1-7

Alto Chicama Coal Reserves

Category	Reserves(metric tons)
Proven	25,222,741
Probable	34,478,764
Possible	<u>211,137,134</u>
Total	270,838,639

Source: Ref. 4

2.0 Nuclear Fuels:

The geology of Peru holds promise of having commercial resources of uranium. A limited exploration, conducted mostly in the 1950s through a joint program of the Junta de Control de Energia Atomica del Peru (JCEA, Peruvian Atomic Energy Control Board) and the U.S. Atomic Energy Commission, did not identify any exploitable concentrations of uranium ore. This exploration consisted of an examination of samples from mines and mills for evidence of radioactivity, car mounted scintillometer traverses, and studies of rocks, environments, and mineral zones.⁵

Although a number of uranium minerals and evidence of anomalous radioactivity were observed, no economic concentration of ore was found. Further exploration in a limited area, through aeroradiometric prospecting aided by the International Atomic Energy Agency, was carried out during 1970-1972. An ongoing United Nations Development Program, funded in association with the Instituto Peruano de Energia Nuclear (IPEN, The Peruvian Institute of Nuclear Energy), includes a project of field investigations to determine regions favorable for uranium occurrence. This study is part of Peru's Nuclear Plan for the period 1976-1981, a copy of which is included in Annex-6.

3.0 Renewable Resources

3.1 Hydro power:

The potential water supply and head for hydro power is very large.⁶ As shown in Table B.1-8, the total surface water supply averages about

1.5×10^{12} cubic meters annually. The drainage area totals 1,285,220 square kilometers, of which about 11 percent drains to the Pacific and the remainder to the Atlantic and Lake Titicaca.

Table B.1-8

Surface Water Supply of Peru

<u>Watershed</u>	<u>Surface Water Supply ($10^6 \text{ m}^3/\text{year}$)</u>	
	<u>Total</u>	<u>Developable</u>
Pacific	33,972	20,577
Atlantic	1,437,000	29,732
Titicaca	23,705	702
Total	1,494,677	51,011

Source: Ref. 6

The Pacific or western portion has a mean annual runoff ranging in depth from zero, along portions of the coast, to about 400 millimeters in the Santa River basin in northern Peru. In contrast, the eastern or Atlantic portion has a mean annual runoff ranging in depth from about 300 millimeters to over 1,800 millimeters. Mean annual rainfall in the Atlantic drainage basin ranges from a low of 603 millimeters in the Nieva River Basin to about 3400 millimeters in the Madre de Dios.

During the 1960s, the Government of Peru, with the assistance of the Government of the Federal Republic of Germany, undertook an assessment of the future demand for electric energy and the hydroelectric potential of Peruvian water supplies. Both were carried forward to the year 1985. The Government of Peru is currently engaged in updating its previous assessment in cooperation with the Federal Republic of Germany. 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 country's electrical supply systems. The completion date for this program is March 1979.

A preliminary account of the hydro power potential by river basins in the Pacific, Atlantic, and Lake Titicaca areas of Peru is detailed

in Reference 6. Estimated hydro power potential by the principal drainage areas is shown in Table B.1-9.

Table B.1-9

Estimated Hydro Power Potential

Drainage	Mw
Pacific	29,954.5
Atlantic	163,617.5
Lake Titicaca	<u>557.0</u>
Total	194,129.0

Source: Ref. 6

It is estimated that approximately 70 percent of the hydroelectric potential is not exploitable due to geographic, topological, and cost restrictions. (The remaining 58,000 megawatts still exceeds the 1977 installed hydro capacity by more than 40 times.) The existence of conflicting uses, such as irrigation, further restricts the achievable hydroelectric capacity, but the complex nature of such considerations has prevented their quantification. In addition, most of the estimated hydro power potential is associated with the rivers on the eastern side of the Andes range that drain into the Amazon basin. Since this region is remote from the main load centers of coastal Peru, diversion of rivers and/or extensive high voltage transmission lines would be necessary to translate the achievable hydro potential into reality. At present, transmountain diversions of water from the Marañon and Mantaro River systems of the Atlantic watershed are used to supplement the available water supplies in the Pacific area.

3.2 Biomass:

Peru's biomass resources are comprised of wood (from natural forests, plantations, and orchards), agricultural crop residues, and animal wastes. Most of the energy needs of the rural population are met by biomass. Firewood is the dominant biomass resource utilized. In particular

geographic areas, animal wastes (dung) and agricultural residues (sugarcane bagasse) are also used in significant amounts. Biomass can have an increased importance in meeting Peru's future energy needs if a well-managed program of resource development and utilization is implemented.

Forest Resources

Peru has abundant forest resources. About 60 percent of its total land surface is covered by natural or cultivated forests. Table B.1-10 identifies the distribution of natural forests and the areas potentially suitable for reforestation among the three major geographical regions: the Costa, the Sierra, and the Selva. The energy potential of this resource, on a renewable basis, is very large; in fact, it is an order of magnitude larger than the gross primary energy consumed currently in Peru. Under a forest management scheme, sustainable annual yields of about 10m³ of wood per hectare could be obtained on a reasonably conservative estimate. Assuming the density of wood to range from 0.3 to 0.5 ton per m³ and the heat value between 13 to 18 billion joules per ton, the gross primary energy available from forests annually would be in the range of 2900 to 6700 quadrillion joules. However, the ability of this resource to significantly contribute to Peru's energy needs outside of the traditional rural domestic sector is limited by a number of constraints. As Table B.1-10 illustrates, almost 99 percent of the resource is located in the thinly populated Selva region. The fragile ecology of the Amazon rain forest poses significant problems to a viable large-scale forest management scheme if environmental damage is to be avoided. Moreover, to transport this energy in significant amounts to the main energy consuming areas in coastal Peru, either in the form of wood itself, or in the form of secondary products (charcoal, electricity, etc.) would require an elaborate and extensive transportation/transmission system whose logistics and economics would be certain to pose major problems.

Table B.1-10

Natural Forest and Land Capable of Supporting Reforestation
(10³ ha)

Region	Natural Forest	Plantations	Land Suitable for Planting
Costa	950	6.7	493
Sierra	50	97.7	7,402
Selva	<u>73,000</u>	<u>1.8</u>	<u>2,498</u>
TOTAL	74,000	106.2	10,393

Source: Ministerio de Agricultura, Vademecum Forestal, Lima, Peru, 1977.

Table B.1-11 gives production figures for firewood and other forest products based on data from the Minister of Agriculture and the Food and Agriculture Organization (FAO) of the United States.

Table B.1-11

Production of Fuelwood and Forest Products in Peru, 1975

Product Category	Production (10^3 m^3)		Estimated Energy Value ³ (10^{15} Joules)	
	Min. of Agr. Data ¹	FAO Data ²	Min. of Agr. Data	FAO Data
Firewood	2,580	5,747	23.2	51.7
Charcoal	19	0	.2	0
Forest Industry Products	578	705	5.2	6.3
Forest Industry Wastes	503	-	4.5	-
Pulpwood	23	23	.2	.2
Other	<u>370</u>	<u>87</u>	<u>3.3</u>	<u>.8</u>
Total	4,073	6,652	36.6	59.0

¹Ministerio de Agricultura, "Vademecium Forestal," Oficina de Patrimonio Forestal y Estadística, Lima (1977).

²FAO, "Yearbook of Forest Products 1964-1975," FAO Forestry Series, Rome (1977).

³Energy estimates from Harper, Smith and Mariani, "An Assessment of Peruvian Biofuel Resources and Alternatives," (1978)

Current use of wood and its products in Peru is mostly for fuel (firewood and charcoal) to serve the domestic (energy) needs of rural inhabitants. The proportion of wood used for fiber or feedstock (either in industry or for construction) is small.

There is a large discrepancy between estimates of fuelwood utilization given in Table B.1-11, ranging from the 23 to 50 quadrillion joules(QJ), and other estimates. According to the Plan Energetico A Largo Plazo 1978-1990 Y Perspectivas Al 2000: Diagnostico 1968-1977, the energy from firewood amounted to 145 QJ in 1976, while the UNDP Energy Balances Project estimated the same number at 120 QJ. The estimates in this report (see Appendix B3), based on an analysis of the energy requirements of rural households for cooking and water heating, lead to a figure of about 138 QJ of firewood use in 1976. The discrepancy between the latter estimates and the official figures probably arise from the fact that official statistics only take reported use of round wood into account. Most of the rural households probably forage wood from branches and twigs of trees along irrigation canals or on the perimeter of rural settlements, which are not accounted for in the forest inventory.

Agricultural residues

Approximately two percent of Peru's land area, amounting to about 2.6 million hectares, is under agricultural cultivation. Table B.1-12 shows the cultivated area, the agricultural residues produced, and their energy content in the three major regions of Peru.

Table B.1-12

Cultivated Areas and Agricultural Residue
Production for Major Regions in Peru, 1976

Region	Area Cultivated (Hectares)	Agricultural Residue Production (10 ³ Metric Tons)	Estimated Energy Value (10 ¹⁵ Joules)
Costa	702,780	4,518	53.05
Sierra	1,165,543	997	13.14
Selva	616,604	753	9.81
National	2,484,927	6,268	76.00

Source: Anuario Estadístico Agropecuario (1976), Ministerio de Agricultura y Alimentación OSEI, Lima, Peru. Residue estimates from Harper, Smith & Mariani, "An Assessment of Peruvian Biofuel Resources and Alternatives." Annex-8.

The total biomass resource of all the agricultural residues at current production levels amounts to about 76×10^{15} joules. Of all the crops grown in Peru, only one, sugarcane, is presently a significant factor in the energy situation. Sugarcane residue, or bagasse, is extensively used as a boiler fuel and serves part of the process steam and electricity requirements of the sugar industry. In 1976, it is reported that bagasse provided about 9×10^{15} joules of primary fuel for electric power generation in the sugar industry. The remainder of the bagasse, amounting in energy content to about 25×10^{15} joules, is assumed to have been used to provide process heat for sugar refining and also used as a feedstock for the paper industry. Another by-product of sugar processing, molasses, is fermented into ethanol. This ethanol is used for production of PVC rather than as fuel. According to the Banco de la Nacion, 30.4 million litres of ethanol were produced from sugar processing in 1976.

The entries in Table B.1-12 illustrate the potential energy resource availability from agricultural residues. The residues from major agricultural crops other than sugar cane are not currently used for fuel. Their distribution throughout the country is highly dispersed and their residues are not concentrated by the need for centralized processing as is the case with sugarcane. Thus, it is not realistic to assume that this resource could be utilized fully for energy conversion.

Animal Waste

The major portion of livestock, apart from poultry, is located in the Sierra. In settlements in Sierra highlands above the tree line, animal dung from alpacas, llamas, and cattle has been used for many centuries as a source of fuel. The dung is collected, fashioned into bricks, and dried in the sun.

Table B.1-13 provides data on the 1976 livestock population in Peru, as well as estimates of the residues generated and their energy content (based on 14.6×10^6 joules/ton of dry residue). The total energy content of these residues amounted to about 170×10^{15} joules in 1976. According to the UNDP Energy Balances Project about 10×10^{15} joules of animal waste were utilized as cooking fuel in 1976.

Table B.1-13

Livestock Population and Estimated Residue Production, 1976

Animal	Population (10 ³ Head)	Estimated Annual Residue Production/Head (Ton/Year)	Estimated Annual Residue Production (10 ³ Tons)	Estimated Energy Value (10 ¹⁵ joules)
Alpacas	2445	0.13	318	4.64
Poultry	37681	0.0011	42	0.61
Goats	2021	0.11	222	3.24
Horses	1327	1.5	1991	29.07
Llamas	1361	0.14	23	0.34
Sheep	15294	0.11	1682	24.56
Pigs	2142	0.11	236	3.45
Cattle	4189	1.7	7121	103.97

Source: As in Table B.1-12

As with agricultural residues, it is not conceivable that all the animal residues resource (amounting to about 170×10^{15} joules annually) would be used as fuel. Of the fraction that is presently collected, the major part is probably used as fertilizer.

3.3 Solar and wind:

There is no existing, comprehensive summary of Peru's solar energy resource by season and geographic region. A preliminary estimate of Peru's solar energy resource base is based on records of duration of "bright" sunshine at 78 sites maintained by the Servicio Nacional de Meteorología e Hidrología (SENAMHI, The National Meteorological and Hydrologic Service). Table B.1-14, based on SENAMHI records, lists the average number of hours of bright sunshine per day by season for 14 selected stations.

For several reasons, the data provide an inadequate description of solar energy resources:

- o Some areas, like the eastern and northcentral regions, are not adequately represented by the sunshine duration stations.
- o The data must be converted into energy units.
- o The data does not describe the real variations in the solar resources which can be expected day-to-day or year-to-year.

Nothing can be done about the first item without more field measurements and analysis, but probably the resource is not too different from that given for the nearest stations. With respect to the third item, solar energy availability from one day to the next can easily change by a factor of two or more. Even the average daily solar energy for a particular month can vary by 10 to 30 percent from one year to the next. However, annual totals would rarely vary by over 10 percent. These are only general rules; to describe the expected variations for Peru would require more information on the frequency distribution of solar radiation.

In order to convert the sunshine duration data into energy data, we have assumed that "bright" sunshine corresponds to 900 w/m^2 radiant energy intensity, on a surface which is oriented normal to the sun's rays. This means that each hour of sunshine is equivalent to 0.9 kwh/m^2 of solar radiation. This conversion is only approximate: sometimes the intensity will be less, and this approximation ignores all conditions of exclusively diffuse radiation. Of course, the amount of solar energy which is intercepted and converted by a solar collector depends strongly on collector design.

Table B.1-14

Daily Hours of Bright Sunshine in Some Selected Areas of Peru

Locality	Fall	Winter	Spring	Summer	Daily OAvg. Hrs.	Avg. Daily Incident Solar Energy* (10 ⁶ joules/m ²)
Abancay	5.5	6.9	6.3	4.4	5.8	18.8
Cajamarca	4.6	6.0	5.2	4.7	5.1	16.6
Chachapoyas	7.1	7.6	7.5	6.9	7.3	23.6
Huanca Bamba	3.9	4.6	4.5	4.0	4.3	13.8
Huanaco	5.6	7.2	5.8	4.6	7.8	18.8
Huancayo	6.9	5.1	6.9	6.8	6.4	20.8
Ica	7.6	6.6	8.0	7.1	7.3	23.6
Lambayeque	6.9	5.5	6.5	7.1	6.5	21.0
Moquegua	8.9	9.5	10.3	7.9	9.2	29.6
Negritos (Talara)	7.5	7.1	7.0	7.2	7.4	24.1
Piura	7.5	6.8	7.8	7.1	7.3	23.6
Puerto Chimbok	5.8	3.1	5.6	6.8	5.3	17.3
Puno	8.0	9.4	8.7	6.5	8.2	26.4
Trujillo	5.1	3.4	4.4	5.6	4.6	15.1

* One hour of bright sunshine = 0.9 kwh/m^2 of incident radiation on a normal surface
 = $3.2 \times 10^6 \text{ joules/m}^2$

Source: The Peruvian National Meteorological and Hydrologic Service

According to Table B.1-14, areas in southern Peru such as Piura, Arequipa (Moquega) and Puno have excellent solar resources with insolation of about $2500 \text{ kwh/m}^2\text{-yr}$ ($9 \times 10^9 \text{ joules/m}^2\text{-yr}$). Much of the Sierra region has moderate solar availability with insolation levels averaging about $1900 \text{ kwh/m}^2\text{-yr}$ ($6.8 \times 10^9 \text{ joules/m}^2\text{-yr}$). The areas with the lowest solar resources are coastal regions such as Lima, which have a persistent cloud cover for about four months of the year.

Data on the wind energy resources of Peru are also very inadequate. Although there are several hundred wind recording sites, the data available are limited to magnitude and direction measurements just three times a day at unknown heights above the ground. Table B.1-15 shows average annual wind speeds, averaged over the last five years at some selected sites in Peru. Good wind resources are indicated along the southern coast as the stations Ocona and Punta de Coles show annual average wind speeds of about 5.4 m/s (12 mph). Available data for the Sierra region (Otuzco, Tayabamba and Lampas Alto) indicate only marginal wind resources, but further measurements in more exposed areas will probably reveal sites with good wind availability, typical of mountainous areas. Wind resources in the Selva seem to be very limited as the data for Iquitos (Zungacocha), Tournavista, and Inopari indicate.

Table B.1-15
Annual Average Wind Speeds

Station	Lat.	Long.	m/s.	mph
Zungacocha	3.8	73.3	1.0	2.2
Tumbres	3.6	80.5	2.0	4.5
Cruzeta	4.9	80.3	3.7	8.2
Sayobar	5.8	81.0	2.4	5.5
Rioja	6.0	77.2	0.39	0.87
Juancita	6.0	74.9	1.0	2.2
Olmos	6.0	79.8	3.2	7.2
Otuzco	7.9	78.6	1.5	3.3
Tournavista	8.9	74.7	0.0	0.0
Tayabamba	8.3	77.3	3.5	7.8
Pampa Whaley	10.9	75.3	0.44	0.99
Lampas Alto	10.1	77.2	3.4	7.7
Inopari	11.0	69.6	1.2	2.7
Quillabamba	12.9	72.7	3.3	7.4
Nana	12.0	76.8	2.2	4.8
Accnococho	13.2	75.1	2.8	6.3
Sicuaní	14.3	71.2	3.1	7.0
Puno	15.9	70.0	2.8	6.3
Acari	15.4	74.6	2.7	6.0
Ocona	16.4	73.1	5.2	11.6
Punta de Coles	17.7	71.4	5.6	12.4

Source: The Peruvian National Meteorological and Hydrologic Service.

3.4 Geothermal:

According to the resource definitions of the U.S. Geological Survey (Geological Survey Circular 726, 1975) Peru's geothermal energy resource base includes all of the stored heat above 15°C, to a depth of 10 km. Geothermal resources are defined as stored heat, both identified and undiscovered*, that is recoverable, using current or near-current technology, regardless of cost.

*Identified resources are specific bodies of material whose location, quality, and quantity are known from geologic evidence supported by engineering measurements. Undiscovered resources are unspecified bodies of material surmised to exist on the basis of broad geologic knowledge and theory. (U.S.G.S. Bulletin 1450-A)

For the purposes of this assessment, Peru's geothermal resources can be subdivided into inferred resources and speculative resources. (See Footnote to Table B.1-16 for a definition of these categories.) The existence of these resources is indicated by the chemical and physical character of the hot springs in many parts of the country, a broad knowledge of the geologic characteristics where economically exploitable geothermal resources tend to occur, and analogy to demonstrated geothermal reserves in northern Chile. The inferred resources are all found in southern Peru in areas of recent and active volcanism. These areas are shown in Fig. B.1-3 as Zone V. Speculative resources exist in central and northern Peru, generally in a narrow belt of hot spring activity within the Cordillera Occidental (Zones I, II, III, and IV in Figure B.1-3) and in a zone extending from Cuzco to Puno (Zone VI, Figure B.1-3). These resources are termed speculative because it has not been demonstrated that significant amounts of geothermal energy can be economically extracted from the particular type of geological environment encountered there.

Based on limited available information, only the Calacoa area in southern Peru is considered to have inferred resources which could be economically exploited. The general character of the hot spring activity there is indicative of a hot water dominated reservoir with a temperature greater than 180°C. In other places in the world, the electric power potential of hot water dominated reservoirs is generally in the range of 30 to 250 MWe. A value of 100 MWe has been arbitrarily assigned to Calacoa in this assessment. The electrical energy potential of geothermal resources is usually stated in terms of megawatt.centuries (MW.cent). One MW.cent is equivalent to 1 MWe of power being continuously produced over 100 years. Assuming the geothermal resources in Calacoa to be sustainable over 50 years, the inferred resources would amount to 50 MW.cent. This is equivalent to 1.6×10^{16} joules.

The numbers in Table B.1-16 for the speculative resources were derived by assuming that at least four of the nine large active volcanoes in Peru have associated active hydrothermal systems, and that at least eight to ten other hydrothermal systems are present near volcanoes that are no longer considered to be active. Additional study of the many relatively insignificant hot springs in Zone V may elevate many of the speculative to inferred resources. However, it is likely that many exploitable geothermal systems in Peru have no hot spring or fumarole surface expression, either because the systems are too young or because abundant, cold, shallow ground water completely masks the deep hot water. These systems with no surface hot springs might be located by geologic and geophysical surveys.

Table B.1-16

Estimated Geothermal Resources of Peru

Temperature Regime	Resources ^a MW.cent	10 ¹⁵ Joules
Over 180°C		
Inferred ^b	50	160
Speculative ^c	1,000	3,200
Under 180°C		
Inferred	150	480
Speculative	3,000	9,600

^aGeothermal energy resources are defined in terms of megawatt.centuries (MW.cent). One MW.cent is equivalent to 1MW of power produced continuously for 100 years. It is also equivalent to 3.15×10^{15} joules.

^bInferred reserves or resources are based largely on broad knowledge of the geologic character of the deposits and for which there are few, if any, samples or measurements. The estimates are based on assumed continuity or repetition, of which there is geologic evidence. This evidence may include comparisons with deposits of similar types. Bodies that are completely concealed may be included if there is specific geologic evidence for their presence (U.S. Geological Survey Bulletin 1450-A, 1976).

^cSpeculative resources are undiscovered resources that may occur either in known types of deposits in a favorable geologic setting where no discoveries have been made or in as yet unknown types of deposits that remain to be recognized (U.S. Geological Survey Bulletin 1450-A, 1976).

Source: Annex 1

FIG B.1-3 MAP OF GEOTHERMAL REGIONS OF PERU

Notes and References to Appendix B.1

1. U.S. Geological Survey, "The Energy Resources of Peru," Annex-1 to this report, October, 1978.
2. Data for 1965-1975 from "World Energy Supplies 1950-1975", 1977, Department of Economic and Social Affairs, United Nations, N.Y. Data for 1976 from Airgram, "Annual Petroleum Report: Peru--1976," (May 1977), U.S. Department of State.
3. Petroleos del Peru, Carta de Noticias (March 7, 1978).
4. Annex-1 to this report.
5. U.S. Geological Survey, U.S. Bureau of Mines, U.S. Bureau of Reclamation, and Argonne National Laboratory, "Preliminary Report on the Energy resources of Peru," pp. 62-3.
6. Paul Willmore and John Steele, "Report on Hydro Power--Peru," Annex-5 to this report, July, 1978.
7. This section is based on a report by J. Harper, W. Smith and E. Mariani, Annex-8 to this report.
8. This section is based on a report by E. Boes, Sandia Laboratory, and P. Teegan, Arthur D. Little, Inc., Annex-7.

APPENDIX B.2

THE ELECTRIC SECTOR

APPENDIX B.2 - THE ELECTRIC SECTOR

1.0 INTRODUCTION

Electric energy requirements in 1976 were 7,911 gigawatt-hours (Gwh); total installed capacity was 2,516 megawatts (MWe). At present, this system is based principally on hydroelectric generation, although substantial thermal capacity exists, most of which is fueled by petroleum products. Development plans call for additional hydro power capacity and the introduction of indigenous coal to fuel a steam power plant.

Nearly 60 percent of the electric energy capacity is government owned; the rest, owned by various industrial, mining, and agricultural enterprises, is classified as "autoproduktores". Plans for connecting existing independent public sector systems into three integrated sub-systems have been prepared. Organization of the electric sector in 1976 is outlined below. Likely future developments are covered in Section 3.0 of the Main Report.

2.0 ORGANIZATION

The public sector consists of ElectroPeru (the state-owned utility) various municipal utilities, and other publicly-owned enterprises. The "autoproduktores" generate electric energy for consumption in various industrial enterprises and for use elsewhere. The recent nationalization of privately owned enterprises brought several "autoproduktores" into the public sector. Data on installed capacity and electric energy produced by both sectors in 1976 are furnished in Table B.2-1. In 1976, public authorities generated 64 percent of total electricity produced and owned 59 percent of total capacity.

The state-owned utility, ElectroPeru, includes 12 systems that are now unconnected systems. These systems are listed in Table B.2-2 together with an indication of their planned status within the three integrated sub-systems that ElectroPeru plans to establish.

Table B.2-1

Installed Capacity and Electric Energy, 1976

	Installed Capacity (Mw)	Energy Produced (Gwh)
Public Sector	1,495	5,032
Autoproduktores	1,021	2,879

Source: Ref. B.2-1

The maps in Figures B.2-1, 2, and 3 show the existing Peruvian systems. A single interconnected system that supplies the Lima-Callao area exists in the central region. This system has non-automatic generating equipment and is controlled from ElectroLima's headquarters in the capital.

Other unconnected public sector supplies in the central area include the generating system of Centromin and various isolated plants operated by municipalities. The Centromin system is to be interconnected with Electro-Peru's Centro Norte system in 1980.

Management of ElectroPeru is the responsibility of the Ministry of Energy and Mines. Responsibility for electricity demand projections, however, rests with the Direccion General de Electricidad (General Electricity Board), another component of Energy and Mines. Electric system analysis is accomplished by the Instituto de Investigaciones Energeticas y Servicios de Ingenieria Electrica (Institute of Energy Research and Electrical Energy Services, INIE), while capacity expansion planning is shared by INIE and the Direccion General de Electricidad. The development of nuclear energy is handled by the Instituto Peruano de Energia Nuclear (Peruvian Nuclear Energy Institute, IPEN). Both INIE and IPEN are also components of the Ministry of Energy and Mines.

3.0 ELECTRIC ENERGY DEMAND

Yearly statistics supplied by the Ministry of Energy and Mines show that in 1976 industry and mining consumed 45 percent of total gross electricity produced, while residential customers consumed 17 percent (Figure B.2-4). According to the 1972 Census of Housing, only 32 percent of total households have access to electricity.

Annual growth rates in electricity consumption for the 12 years prior to 1976 are shown in Figure B.2-5. The 12-year average annual growth rate is 6.5 percent, but the rate is quite volatile, ranging from a high of 9.3 percent to a low of only 2.9 percent (in 1974-75).

Of the total of 7,911 gigawatt hours, 47 percent was consumed in the Department of Lima. The Department of Junin, adjacent to Lima, accounted for 11 percent. Thus, the capital region and its environs consumed about 58 percent of the electric energy generated in Peru.

4.0 INSTALLED CAPACITY AND ELECTRICITY PRODUCTION

Electricity generation capacity in the public sector is principally hydroelectric, while that for the "autoproduktores" is either oil-fired steam or diesel. A breakdown of generation capacity, shown in Table B.2-3 reveals 77.3 percent of public sector capacity to be hydroelectric and 75.5 percent of "autoproduktores" capacity to be thermal. The principal generating facilities of the ElectroPeru systems are listed in Table B.2-4.

Table B.2-2
Non-connected Utility Systems (ElectroPeru)

System	Future Interconnection Plans
Tombes-Zorritos-Zarumilla	With Centro Norte ^a
Talara-Verdeur-Malacos	With Centro Norte ^a
Chiclayo	With Centro Norte ^a
Santa	With Centro Norte ^a
Cahua-Paramonga	With Centro Norte ^a
Electrolima	With Centro Norte ^a
Mantaro	With Centro Norte ^a
Macchu Picchu	With Sur Este ^b
Arequipa	With Sur Oeste ^c
Aricota-Southern Peru Copper	With Sur Oeste ^c
Iquitos	No interconnection planned
Pucallpa	No interconnection planned

^a North Central interconnected system.

^b Southeast interconnected system.

^c Southwest interconnected system.

Source: Ref. B.2-2

FIG B.2-1 PRINCIPAL ELECTRIC SYSTEMS OF THE SOUTH REGION

FIG B.2-2

PRINCIPAL ELECTRIC SYSTEMS OF THE CENTRAL SYSTEM

FIG B.2-3

PRINCIPAL ELECTRIC SYSTEMS OF THE NORTH REGION

FIG B.2-4 ANNUAL GROWTH RATES IN ELECTRICITY CONSUMPTION. 1964 - 1976

FIG B.2-5

ELECTRIC ENERGY CONSUMED, 1976

Generating capacity grew 30.4 percent in the 1972-1976 period, with hydroelectric capacity up some 33 percent and thermal capacity up 27 percent. The increase in capacity of the ElectroPeru system was 39 percent during the same period and 19 percent for the "autoproduktores."

Since a philosophy of giving priority to the productive sectors underlies capacity expansion planning, these statistics are evidence of relatively low growth in these sectors during the period 1972-76. Annual growth rates in installed capacity in this period (Table B.2-5) show higher growth for hydro in 1972-74, followed by higher growth in thermal in 1975-76. The inverse relationship between thermal and hydroelectric capacity additions, apparent during the period 1972-76 reflects capital shortages, which force the choice of a fuel-intensive over a capital-intensive production technology even in the face of increasing fuel costs. This is of particular concern in the Centro-Norte region where some unconnected load centers (most importantly, Piura and Chiclayo) are expecting capacity shortfalls over the next four years. ElectroPeru is planning to install diesel generators to meet demand until these systems can be connected to the grid.

The principal generating systems associated with individual enterprises are those of Centromin and Southern Peru Copper Company (SPCC). The electricity generating capacity of Centromin, the state-owned mining enterprise in Central Peru, will not be fully integrated into the ElectroPeru system until 1980, when 222 kilovolt and 138 kilovolt transmission links are complete. The capacity of the existing Centromin

Table B.2-3

Generating Capacity (MWe), 1976

	<u>Hydroelectric</u>	<u>Thermal</u>			<u>Total</u>
		<u>Steam</u>	<u>Gas Turbines</u>	<u>Diesel</u>	
Public Sector	1,156.0	14.5	143.9	180.6	1,495.0
Autoproduktores	<u>249.8</u>	<u>387.5</u>	<u>87.9</u>	<u>295.6</u>	<u>1,020.8</u>
Total	1,405.8	402.0	231.8	476.2	2,515.8

Source: Ref. B.2-1

Table B.2-4

Generating Facilities: ElectroPeru System, 1978

<u>System</u>	<u>Subsystem</u>	<u>Plant</u>	<u>Capacity (MWe)</u>		<u>Type</u>
Centro-Norte	Piura	Piura	19		Fossil
		Malacao	54		Fossil
		Total		73	
	Lambayeque	Chiclayo	51	51	Fossil
	Chimbote-Trujillo	Canon Del Pato	100		Hydro
		Chimbote-Trujillo	80		Fossil
		Trupal	28	208	Fossil
	Lima	ElectroLima	591		Hydro
		HierroPeru	66		Fossil
		Mantaro	342		Hydro
		CentrominPeru	183		Hydro
		Paramonga	22		Fossil
		Cahua	40		Hydro
				1243	
				1576	
Sur Oeste	Arequipa	Charcani I,II,III,	6.8		Hydro
		Charcani IV	14.4		Hydro
		Charcani VI	9.0		Hydro
		Chilini I,II	12.0		Fossil
		Diesel Cerro Verde	5.0		Fossil
		Cerro Verde I	16.5		Fossil
		Cerro Verde II	16.5		Fossil
				80.2	
	Aricota-Southern Peru Copper Co.	Aricota	35.3		Hydro
		Ilo A	66.0		Fossil
		Ilo B	44.0		Fossil
		Ilo C	66.0		Fossil
		Diesel Toquepala	5.3		Fossil
				216.2	
				296.8	
Sur Este		Machu Picchu	40		Hydro
		Dolores del Pata	8.1		Fossil
				48.1	

Source: Ref. B.2-2

Table B.2-5
Growth Rates in Installed Capacity
(in percent)

Year	Thermal	Hydroelectric	Average
1972	8.1	6.8	7.45
1973	0.3	21.0	10.65
1974	0.1	8.6	4.35
1975	9.7	0.7	5.20
1976	15.5	0.6	8.05

Source: Ref. B.2-1

interconnection to ElectroLima is 3.5 megavolt amperes (MVA). Principally hydroelectric, the capacity of the Centromin system in 1976 was 183 megawatts. The other significant generating system associated with a large enterprise is that of the SPCC with a generating capacity in 1976 of 176 megawatts (steam turbine). By 1976, this system was fully interconnected with ElectroPeru's Aricota system and it is planned that the SPCC-Aricota system will be interconnected with ElectroPeru's Arequipa system by 1985 to form the Sur Oeste integrated subsystem.

Table B.2-6 summarizes electricity production in 1976 according to sector and type of facility. Based on the figures for installed capacity, from Table B.2-3, load factors for hydroelectric plants (public sector) are 0.46, for thermal plants in the public sector, 0.14, for "autoproduktores" thermal plants, 0.25, and for "autoproduktores" hydro plants, 0.53.

Data on fuels consumed by thermal power plants in both the public sector and by "autoproduktores" are available from the Ministry of Energy and Mines and are presented in Table B.2-7. Small amounts of natural gas are used in the Talara refinery complex and by a nearby public utility. Bagasse, with approximately 11 billion joules per ton energy content, is used as fuel for electric generation by the sugar cane industry. However, this has decreased over the years because bagasse has become a preferred input to papermaking. The data in Tables B.2-6 and B.2-7 yield conversion efficiencies of 25 percent for the public sector thermal plants and an average of 20 percent for the "autoproduktores."

Table B.2-6

Electric Energy Produced (Gwh), 1976

	Hydraulic	Thermal			<u>Total</u>
		<u>Steam</u>	<u>Gas Turbines</u>	<u>Diesel</u>	
Public Sector	4,623.4	93.8	7.3	357.4	5,081.9
Autoproductores	<u>1,174.3</u>	<u>1,163.3</u>	<u>121.0</u>	<u>420.7</u>	<u>2,879.3</u>
Total	5,797.7	1,257.1	128.3	778.1	7,961.2

Source: Ref. B.2-1

Table B.2-7

Fuel In Electric Energy Production, 1976

	Petroleum (barrels x 10 ⁶)			Gas (Cu.Ft. x 10 ⁶)	Bagasse (tonnes x 10 ⁶)
	Crude	Diesel	Residual		
Public Sector	0.1	0.7	0.05	0.6	0
Autoproductores	<u>1.0</u>	<u>0.8</u>	<u>1.2</u>	<u>3.3</u>	<u>0.8</u>
Total	1.1	1.5	1.25	3.9	0.8

Source: Ref. B.2-1

Notes and References to Appendix B.2

1. Ministerio de Energia y Minas, Direccion General de Electricidad, "Anuario de Estadistica Electrica, 1976."
2. Ministerio de Energia y Minas, Direccion General de Electricidad, Direccion de Desarrollo Electrico, "Plan de Electrificacion Nacional, Segundo Reajuste, Periodo 1978-1990," Lima, Peru, December, 1977.

APPENDIX B.3

REFERENCE ENERGY DEMAND PROJECTION

APPENDIX B.3 - REFERENCE ENERGY DEMAND PROJECTION

1.0 HISTORICAL TRENDS

This section describes trends in consumption of petroleum products, natural gas, coal and coke, and noncommercial fuels. The next section describes the sectorial consumption patterns and projections.

Total energy resource consumption in Peru grew at an average annual rate of 3.2 percent in the last decade, from about 379×10^{15} joules in 1965 to 538×10^{15} joules in 1976. During this period, per capita energy consumption remained stable at about 34×10^9 joules. Consumption of commercial energy resources has grown at a faster rate, 5.1 percent, than total energy; its share grew from about 56 percent in 1965 to 68 percent in 1976.

Figure B.3-1 shows the energy resource consumption by type and relative market share in 1965 and 1976. The consumption of oil, which grew at an average annual rate of 4.6 percent during the last decade, accounted for the largest fraction of the total commercial energy consumed in 1976.

Hydro power was the fastest growing energy source between 1965 and 1976, with an average annual growth rate of 7.3 percent. Its relative share of commercial energy (expressed as fossil fuel equivalence) was estimated to have been 18.9 percent in 1976. The relative share of natural gas consumption over the same period has remained within a narrow range. Coal consumption figures are quite uncertain. Those shown here incorporate crude estimates of unreported production. According to these estimates, coal's relative share of commercial fuels has remained constant.

1.1 Consumption of Petroleum Products.

Like most other countries, Peru depends heavily on petroleum products for its fuel needs. Gasoline and diesel oil are used for transportation, kerosene and liquefied petroleum gas (LPG) for residential cooking and lighting, and residual and diesel oil for electric generation, industrial, and agricultural activities. Table B.3-1 summarizes the use of petroleum products by consumption sector for 1976. Transportation is fueled entirely by petroleum and uses 43 percent of the total oil consumption; industrial consumers use 34 percent (21 percent of this amount in turn provides for internally generated electricity); domestic and commercial users 13 percent; agriculture 3 percent; and public utilities 2 percent. In 1976, 64 percent of the oil consumed was obtained from domestic production, and 33 percent from imports. Ecuador accounted for 75 percent of crude imports, Venezuela 21 percent, and Colombia the remainder. Imports of refined petroleum products (from Venezuela, the Dutch Antilles, Brazil, and others) amounted to only 3 percent of petroleum consumption in 1976.

FIG B.3-1 ENERGY CONSUMPTION. 1965-1976.

Table B.3-1

Consumption of Petroleum Products by Sector, 1976

(10¹⁵ joules)

<u>Sector</u>	<u>Gasoline</u>	<u>Aviation Fuels</u>	<u>Diesel & Residual</u>	<u>Kerosene</u>	<u>LPG</u>	<u>Other</u>	<u>Total</u>
Mining	1.17 ^b		20.87	0.76			22.80
Fishing			14.82	—			14.82
Manufacturing			46.39	1.28			47.67
Construction			2.67	—			2.67
Agriculture	0.47		7.54	0.43			8.44
Public Utilities			5.18				5.18
Armed Forces	1.42	0.49	3.04				4.95
Transportation	66.19	13.60	31.3				111.09
Domestic & Other				28.27	5.35		33.62
Non-Energy Uses ^a	—	—	—	—	—	4.62	4.62
Total	69.25	14.09	131.81	30.74	5.35	4.62	255.86

^a Consists of 34 percent lubricants, 38 percent asphalts, 22 percent hexane and solvents, and 6 percent greases.

^b Included under transportation energy use in the analysis.

Source: Direccion General de Hidrocarburos, Ministerio de Energia y Minas. Different sectoral definitions by PetroPeru account for different sectoral breakdown of petroleum consumption in tables based on PetroPeru data.

In the past 10 years, the consumption of petroleum products has been characterized by a rapid penetration of liquified petroleum gas (LPG), large growth rates in demand for jet fuel (in part through replacing other aviation fuels, but mostly from increased demand for jet fuel itself), and sustained growth rates for diesel fuel (4.8 percent

per year) and kerosene (3.9 percent per year). Table B.3-2 shows sales in selected years in the 1966-1976 period. Residual oil consumption shows a 10-year growth rate of only 2.6 percent and is low throughout the period (*i.e.* the growth rate does not appear to be influenced by the post-1975 economic crisis). The statistics for gasoline, however, show this downturn quite clearly. The average growth rate in 1966-1975 period was 4.5 percent, but by 1976 consumption had dropped below 1974 levels. Price increases, also a major factor, are discussed below.

Responsibility for marketing of petroleum products rests primarily with government-owned PetroPeru. Except for LPG, which is handled by independent gas distributors, sales of petroleum products to final consumers in urban areas are made via PetroPeru-owned gasoline stations. Kerosene distribution to remote rural areas is carried on by independent retailers.

Short-term issues concerning petroleum products are tied to the present economic climate and the recent price increases instituted by the Government of Peru. The retail price of gasoline in June of 1978 was 145 soles per gallon (95 cents per gallon), up drastically from a year earlier. The price of diesel is only 70 soles (46 cents) per gallon, and a switch to diesel by trucks and buses is taking place. The price history for petroleum products from mid-1975 to January 1978 is shown in Table B.3-3.

1.2 Consumption of Natural Gas

At present, all natural gas produced in Peru is associated gas from oil wells. Total annual production in the past decade has ranged between 65 and 76 billion cubic feet (see Table B.3-4), obtained from onshore and offshore operations in the North. Only a fraction of the wet natural gas produced is used as a fuel. Of the 71.6 billion cubic feet (BCF) produced in 1976, a little over 40 percent was refined and the rest was flared or used in extraction activities (see Table B.3-5). Consumption of refined natural gas is not adequately documented and most of its use is internal to PetroPeru's refining operations in the Talara area, except for 1.46 BCF (1.74×10^{15} joules) used in 1976 as feedstock for a urea plant. The remainder, about 17.2 BCF (18.7×10^{15} joules) in 1976, is allocated in this study to miscellaneous process heat uses, although it is probable that part of this gas is flared.*

*Electric power statistics indicate that 3.5×10^{15} joules of natural gas are used for electric generation by refineries and 0.7×10^{15} joules by public utilities in the northern region. PetroPeru officials cite figures of 2.6 BCF used as residential fuel in the Talara-Negritos area, serving a population of about 80 thousand, as cooking fuel, leaving a balance of some 12 BCF. More than half of this latter amount is actually flared.

Table B.3-2
Petroleum Products Sales, 1966-1976

	<u>In thousands of barrels</u>						
	<u>1966</u>	<u>1968</u>	<u>1970</u>	<u>1972</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>
LPG	309.8	436.5	614.3	784.9	1,107.5	1,234.4	1,264.5
Gasoline	8,915.2	9,379.7	10,141.4	11,378.3	12,567.1	13,235.8	12,499.4
Kerosene	3,516.8	3,761.2	4,064.7	4,337.8	4,337.8	4,939.8	5,140.0
Diesel	5,470.0	6,088.1	6,768.7	6,444.4	7,509.8	8,101.3	8,685.7
Residual	9,176.8	9,805.1	10,361.8	9,969.7	11,421.4	11,532.0	11,830.7
Aviation Fuel	380.7	303.9	216.0	240.4	148.5	106.5	94.5
Jet Fuel	959.6	1,249.7	1,475.2	1,512.8	2,142.3	2,324.6	2,455.9

Source: Ref. B.3-1

Table B.3-3

Retail Prices of Petroleum Products

(per gallon)

(Figures in parenthesis indicate prices in U.S. dollars calculated at exchange rate existing at time of increase.)

Product	6/30/75 (43.38=\$1)	1/13/76 (45.00=\$1)	7/1/76 (65.00=\$1)	6/11/77 (78.55=\$1)	10/10/77 (80.88=\$1)	1/18/78* (130.00=\$1)
<u>Motor Gas</u>						
95 Octane	30.00 (\$0.69)	42.00 (\$0.93)	80.00 (\$1.23)	110.00 (\$1.40)	110.00 (\$1.36)	110.00 (\$0.85)
84 Octane	15.00 (\$0.35)	23.00 (\$0.51)	50.00 (\$0.77)	75.00 (\$0.95)	75.00 (\$0.93)	75.00 (\$0.58)
<u>Kerosene</u>						
Industrial	5.50 (\$0.13)	6.20 (\$0.14)	7.44 (\$0.11)	18.00 (\$0.23)	23.40 (\$0.29)	30.50 (\$0.23)
Domestic	1.75 (\$0.04)	a/	a/	10.00 (\$0.13)	10.00 (\$0.12)	10.00 (\$0.08)
<u>Diesel #1</u>	5.45 (\$0.12)	6.05 (\$0.13)	7.25 (\$0.11)	17.50 (\$0.22)	22.70 (\$0.28)	30.00 (\$0.23)
<u>Residual #5</u>	4.10 (\$0.09)	5.50 (\$0.12)	6.60 (\$0.10)	12.50 (\$0.16)	16.20 (\$0.20)	22.00 (\$0.17)

* Prices were further increased in May 1978.

a/ Production of domestic kerosene was discontinued in the Lima-Callao area between March 1975 and June 1977.

Note: Retail prices are for the Lima-Callao area.Source: U.S. Embassy, Lima, Peru, Annual Petroleum Report--Peru-1977, May 16, 1978.

Table B.3-4

Production of Wet Natural Gas, 1966 - 1976

<u>In billions of cubic feet</u>			
YEAR	ONSHORE	OFFSHORE	TOTAL
1966	64.3	2.1	66.4
1968	65.7	10.1	75.8
1970	51.3	23.5	74.8
1972	41.4	23.0	64.4
1974	36.1	33.8	69.9
1976	34.5	37.1	71.6

Source: Ref. B.3-1

Table B.3-5

Disposition of Wet Natural Gas Production, 1976

<u>In billions of cubic feet</u>	
Liberated to atmosphere	28.74
Used as gas lift	6.32
Used as fuel in oil and gas fields	3.91
Returned to deposits	0.30
Gas lift not recirculated	0.11
LPG	0.08
To urea plant	1.36
To natural gas plants	29.57
Other	<u>1.21</u>
Total wet natural gas produced	71.60

<u>Disposition in Natural Gas Plants</u>	
Used as fuel	17.23
Liquid gas output	2.33
To fertilizer plant	0.10
Used as gas lift, returned to deposit, flared, etc.	<u>9.91</u>
Total inputs to natural gas plants	29.57

Source: Ref. B.3-1

1.3 Consumption of Coal

Coal is consumed almost exclusively in the iron, steel, and non-ferrous metals industry (in the form of coke), although very small amounts are also consumed in the foundries of several mining operations. In 1975, SiderPeru imported 190,000 metric tons of coke from Japan; 51,500 metric tons of bituminous coal was imported from the U.S. for use in lead foundries. In addition, an estimated 12,000 metric tons of domestic production used by other mines and households is cited by INCITEMI for that year. According to this source, none of this domestic production is included in national statistics, and not much is known about its final use.

1.4 Noncommercial fuels

Use of noncommercial fuels comprise an estimated one-third of Peru's total energy consumption. At the same time, they are the only source of energy used by about 40 percent of the population. Noncommercial energy in rural communities is used for cooking and heating. It also fuels local cottage industries such as brickmaking. Firewood is the predominant non-commercial fuel (over 80 percent); the rest is made up of agricultural and animal wastes, plus small amounts of peat. Estimates of the consumption of these fuels are now being made for the Ministry of Energy and Mines.

The only reported industrial use of noncommercial fuel is the consumption of bagasse for electric generation in the sugar industry. In 1976, nearly 800,000 tons of bagasse (9×10^{15} joules) were consumed for this purpose. The remainder of the bagasse (25×10^{15} joules) is assumed to be utilized for providing process heat in sugar refining and as a feedstock for paper manufacturing.

2.0 Sectoral final demands and Reference Projections

2.1 Residential and Commercial Energy Use

The use of fuels in households and commercial establishments is dominated by cooking and lighting requirements. The fuels used are primarily kerosene, a range of noncommercial fuels (principally firewood), electricity, and LPG for middle to high income households. Historically, cooking needs for urban households were met by charcoal obtained from forests in the northern coastal region. These forests are largely depleted (permanent microclimate changes preclude reforestation), and logging operations, lately limited to nonenergy uses of lumber, have been banned altogether by the government. Currently, commercial charcoal suppliers do not officially exist. Town gas was never produced in Peru. The use of natural gas by households is limited to some 15 to 20 thousand homes in the Talara-Negritos area (i.e., near the refinery complex in the oil and gas producing area of the Northwest). This minor usage appears in official statistics as consumption by the oil and gas conversion sector and had been left out of our analysis of the residential sector.

Information on fuel use for the residential and commercial sector is only available in the form of kerosene sales to middlemen (gasoline stations mostly), electricity sales to residential and commercial customers, and LPG distribution. Fuel use by demand category was constructed on the basis of such control totals. Besides cooking, lighting, and electric appliances, dealt with here explicitly, there is a number of uses that have not been examined in detail.

2.1.1 Space Heating. The use of fuels for space heating is limited to electric resistance units, and it is of varying importance, depending on climate zones. A majority of the middle and upper income households which can afford the cost of a heating unit are in the Lima area, which requires little or no space heating (even though the units are ubiquitous in upper income residences). Poorer segments of the population presumably obtain heat from cooking. In the urban centers of the Sierra, such as Cuzco, there is more need for space heating, but since the number of households is small, the energy consumed is also small. The mining towns in the high Andes have substantial space heating requirements, and they obtain free electricity from the mining concerns to meet these needs. Kerosene and LPG heating units are apparently not used in Peru.

2.1.2 Air Conditioning. Even more than space heating, income and climate considerations result in limited use of air conditioning.

2.1.3 Water Heating. The Census of Housing does not provide information on ownership of hot water heaters. The percentage of households with indoor plumbing was only 25.3 percent in 1972 (the proportion is more than two times higher in the large urban centers), and a preliminary survey indicates that these heaters are predominately electric in the \$130 - \$170 per unit price range. In this analysis, this use of electricity is included in "other uses of electricity."

2.1.4 Energy Use in Cooking. Table B.3-6 summarizes the 1972 Census of Housing data on the breakdown of fuels used for cooking. An extrapolation to 1976 shows that 61 percent of urban households use kerosene, 32 percent use LPG, and 7 percent use electricity (excluding the "pueblos juvenes", which almost exclusively use kerosene for their cooking). Urban wastes are employed sporadically in the "pueblos juvenes", but by-and-large they lack access to traditional noncommercial fuels such as firewood and crop residues. Of the total rural households, 13 percent use kerosene, 74 percent use firewood, and 13 percent use other fuels such as dung, as well as peat, which is available at high altitudes in the Sierra.

Conventional gas ranges are priced from \$170 to \$600, while electric stoves go as high as \$800. Kerosene ranges are slightly cheaper than LPG ones, yet they have not gained acceptability, perhaps because they have an unsightly fuel tank and are not completely odorless. There is some incentive to change this situation given refinery limitations on LPG production. A promotional campaign for these ranges, similar to one recently launched by neighboring Colombia, is a possibility.

Table B.3-6

Breakdown of Household Fuels, Peru, 1972 (percent)

	<u>COOKING</u>	<u>LIGHTING</u>
LPG	7.6	
Kerosene	34.7	50.4
Electricity	2.2	32.1
Firewood	43.3	
Candles	—	16.1
Other, not spec.*	<u>12.2</u>	<u>1.4</u>
Total	100.0	100.0

*Includes dung, peat, and urban wastes.

The poorer segments of the population cook with table top kerosene or electric resistance burners. Units with two burners (units also are sold with only one burner) are priced similarly for both fuels at \$90. The kerosene units have storage tanks that hold approximately 2 liters. Single burner kerosene units of simpler construction are reportedly sold at well under half the double burner price.

The estimates of fuel usage for cooking in 1976 are shown in Table B.3-7. Of the total 191×10^{15} joules, 162×10^{15} joules (or 85 percent) are of noncommercial origin. Of these, 138×10^{15} joules correspond to firewood. Although only an estimated 57 percent of the 3,560,000 households in 1976 used noncommercial fuels, the low end-use device efficiency assumed for woodburning devices (one-fourth that of kerosene burners) has an impact on the fuel consumption figures. At $19,000 \times 10^6$ joules/ton, Peru's consumption of firewood in households corresponds to the equivalent of 7.3 million tons of wood.

Table B.3-7

Estimate of Fuel Consumption for Cooking, 1976

10^{15} JOULES	URBAN	RURAL	TOTAL
Kerosene	16.4	6.3	22.7
LPG	5.4		5.4
Electricity	0.7		0.7
Firewood	—	138.0	138.0
Dung, peat, etc.	<u>--</u>	<u>24.0</u>	<u>24.0</u>
Total	22.5	168.3	190.8

2.1.5 Energy Use in Lighting. In 1972, some 32 percent of all households used electricity for lighting, 50 percent used kerosene lamps, and 18 percent used candles. All urban households have access to electricity (older, established "pueblos juvenes" eventually become electrified), and a number of rural isolated systems provide electricity. Under the Housing Census' extremely limited definition of rural communities (clusters of less than 100 housing units), 3 percent of these households had electric lighting in 1972. Kerosene lamps are easily accessible, (they only cost \$2-2.50 each,) and a per household consumption of 3.5×10^9 joules per year, or about 1/2 gallon per week, was obtained. Total fuel use for lighting in 1976 is estimated at $.86 \times 10^{15}$ joules of electricity and 5.6×10^{15} joules of kerosene.

2.1.6 Other Electricity Uses. The balance of electricity used in the residential sector in 1976 is 5.2×10^{15} joules with an additional 2.6×10^6 in the commercial sector. Appliances consist of water heaters, refrigerators, television sets, irons, and sewing machines. The Census of Housing data is an inadequate source for household saturation of appliances, but a privately commissioned survey of 1,500 greater Lima households performed in 1977 reveals extensive ownership of appliances. The results of this survey are summarized in Table B.3-8. Electricity use in the commercial sector is comprised of public street lighting (46 percent of the total electricity to this sector), electricity used by the public waterworks for pumping, and commercial customers, such as office buildings and retail establishments. The latter group (37 percent of the total) uses electricity primarily for lighting.

Table B-3.8

Appliance Ownership by Income Group*
(percent of households)

		High	Middle	Low	Very Low
	Percent of	Income	Income	Income	Income
	Households				
	Owning	(9.9%)	(29.2%)	(47.2%)	(13.7%)
Television Set	76.3	99	95	76	24
Radio	95.8	100	98	97	85
Refrigerator	60.2	99	88	52	1
Cooking Stove	94.0**	100	99	93	81
Washing Machine	32.7	74	60	77	--
Juice/Blender	62.8	97	94	53	5
Sewing Machine	59.5	96	86	52	3
Electric Iron	78.5	100	99	80	16
Stereo	37.6	83	60	25	--
Buffer	30.3	92	56	10	--

* Based on a survey of 1500 households in Lima in May 1977.

** 51 percent of these are LPG, 10 percent are electric, 6 percent are gas-kerosene, and 32 percent are kerosene units.

Source: Ref. B.3-2

2.2 Residential and Commercial Energy Reference Projections

2.2.1 Population and Housing. Peru's population figures are based on the latest available Census of Population taken June 4, 1972. An adjusted population figure of 14.33 million was arrived at for that year, based on an enumerated population of 13.54 million.³ The U.S. Bureau of the Census estimates the population in mid-July of 1977 at 16.36 million and a growth rate of 2.8 percent per year for this period.

Peru's Census of Population defines as urban all population centers that are district capitals or are within a district and larger than the capital. Under this definition, 59 percent of the population lived in "urban" areas in 1972. This definition is inadequate because it includes hundreds of small clusters of housing that belong economically and geographically in a "rural" category. For purposes of this assessment, therefore, urban population is defined as the population of cities which in 1978 had an estimated population of 50,000 persons or more. A list of these 16 cities is presented in Table B.3-9. Figure B.3-2 shows the geographical distribution of these major urban centers. Under this definition, 40.5 percent of Peru's population in 1978 was urban, and 59.5 was rural. It is important to note that a full 64 percent of this urban population lives in the greater Lima area.

2.2.1.1 Housing in 1976. The 1972 Census of Housing indicates the existence of 3,014,844 housing units, yielding an average of 4.70 persons/household for urban areas and 4.21 persons/households for rural areas. These estimates of persons per household had to be revised to match the definition of urban and rural used in this study. Prior to this adjustment, another element of urban housing has to be introduced, the "pueblos juvenes", or urban shantytown.

The specialized literature refers to the makeshift housing that rings most major urban areas in Latin America as "poblaciones marginales", and while in Peru the common name used is "barriada", the official documents use the euphemism "pueblos juvenes", or "young towns". These housing units originate from illegal seizure of farmland or empty spaces by poor rural migrants who first moved into inner city rooming houses and other inadequate quarters. Literally overnight, makeshift communities arise with structures made of wood, matting, cardboard, and other materials. Subsequently, a process of more substantial building develops, leading normally to small brick or cement homes laid out in an urbanized pattern, most with electric, water, and sewer services and usually with unpaved streets. The label "pueblo juvenes" is not removed, however, because nobody has title to the lands and real estate taxes are not levied.

Table B.3-10 shows the percentage of the population living in "pueblos juvenes" in major Peruvian cities for 1961 and 1970. The percentages are extremely volatile because rural-urban migration tends to be directed towards certain cities where jobs are presumably available; there are also inter-urban migrations due to job cutbacks, such as affected the fishing industry.

Table B.3-9

Population in Cities with Estimated Populations
for 1978 in Excess of 50,000

	1978 (THOUSAND)	1975-78 ANNUAL GROWTH RATE
Lima	4,376	4.5
Arequipa	409	4.9
Trujillo	348	5.7
Chiclayo	257	5.1
Chimbote	238	6.3
Huancayo	175	5.3
Puira Castilla	165	4.4
Cuzco	151	3.6
Iquitos	148	4.9
Sullana	123	6.3
Pucallpa	80	5.2
Tacna	79	5.4
Ica	70	1.7
Ayacucho	58	4.7
Pisco	57	5.1
Huanuco	54	4.3
	6,792	4.8

Source: Ref. B.3-42

FIG B.3-2 MAJOR CITIES OF PERU

Table B.3-10

Population in "Pueblos Jovenes" (%)

	1961 ^a	1970 ^b
Pucallpa	22.0	15.9
Chiclayo	34.7	34.8
Trujillo	33.1	63.8
Lima	24.6	25.6
Tacna	14.7	49.7
Puira	34.6	49.6
Arequipa	39.0	37.5
Cuzco	6.2	21.3
Iquitos	61.9	21.7
Sullana	35.5	51.2

a Source: Ref B.3-4

b Source: Ref B.3-5

For 1976, an estimate of urban population living in "pueblos juvenes" of 28 percent was chosen, based on the relative stability of the statistics for Lima and its important weight in the national total. Several sources cite an average of 6.0 persons per household for "pueblos juvenes;" based on this ratio, a calculation yields 4.3 persons/ household in urban households other than "pueblos juvenes." The census figure of 4.2 persons/ household for rural areas was maintained.

Adjusting the 1978 population figures to those of 1976, by applying urban and rural population growth rates (see next section), we obtain the following housing inventory: 1,020,800 urban households, excluding "pueblos Jovenes," 200,000 urban "pueblos juvenes" units, and 2,320,400 rural units.

2.2.1.2 Household Projections. The population figures for 1985 and 2000 used in this assessment were obtained from a demographic study of Peru⁶ published in 1972 which yields a 3.06 percent per annum growth rate between 1960 and 2000. The assessment projects a total Peruvian population of 21.5 million persons by 1985 and 33.5 million by 2000. The growth rate employed here is higher than the rate for the early 70s (2.7-2.8 percent per annum) estimated by the U.S. Bureau of the Census. The critical growth rate, however, is that of urban population. Due to rural to urban migration, the growth of the population of the larger cities is 5.5 percent per year, and that of Lima alone is 4.5 percent. The latter growth rate yields a population of 12 million people in Lima by the year 2000, up from the present 4.5 million.

The number of urban and rural households in the year 1985 and 2000 are presented in Table B.3-11. These were obtained by applying the urban population growth rate and the person per household figures mentioned above. Rural population was obtained as a difference.

An important variable in the analysis was the percentage of urban population living in "pueblos juvenes" in future years. The available literature all pointed in the direction of an increasing proportion of households in these communities. The rural to urban migration results in a need for some 200,000 new units per year. However, less than 50,000 units are built in normal years. During the present recession, construction has been especially depressed.

The proportion of the population living in "pueblos juvenes" in the year 2000 used in the analysis is 35 percent, up from 1976 levels of 28 percent. This figure was taken from a paper by F. Mevius⁷. The 1985 household figures in Table B.3-11 were obtained by interpolation.

Table B.3-11

Population and Household Projections 1985 and 2000
(Thousands)

	<u>1976</u>	<u>1985</u>	<u>2000</u>
Urban Population	6,100	9,380	22,000
of which in "pueblos juvenes"	1,700	2,560	7,700
Rural Population	<u>9,750</u>	<u>12,120</u>	<u>11,500</u>
Total	15,850	21,500	33,500
<hr/>			
Urban Households	1,220	2,011	4,609
of which in "pueblo juvenes"	200	425	1,283
Rural Household	<u>2,320</u>	<u>2,885</u>	<u>2,738</u>
Total	3,540	4,896	7,347

Note:

The Instituto Nacional de Planificacion uses the following estimates of population in its long-term projections: 20.7-21.9 million in 1985 and 29.8-36.3 million in 2000, depending on low and high fertility assumptions.

2.2.2 Derivation of Fuel Mix Tables. The projection of energy demand in the residential sector is tied to the number of urban and rural households estimated above. The reference projection assumes a continued penetration of kerosene in the rural areas, replacing firewood and other noncommercial fuels. This is an uncertain assumption, and alternative energy projections are developed in Section C which incorporate no increased penetration.

The following fuel mix tables detail the derivation of the energy projections.

Table B.3-12

FUEL MIX TABLE*

Sector: Standard Urban Households
End Use: Cooking

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Electricity	0.07	1.0	0.71	0.10	1.0	1.54	0.25	1.0	8.10
Kerosene	0.61	0.4	12.36	0.60	0.4	18.96	0.45	0.4	29.93
LPG	0.32	0.6	5.35	0.30	0.6	7.70	0.30	0.6	16.20
TOTAL FUEL DEMAND, D,									
10^{15} Joules			18.42			28.20			54.23
BASIS: (10^3 Households)	1,020.8			1,580.			3,325.		
SATURATION, S,	1.00			1.00			1.00		

UNIT BASIC DEMAND, E_u 10^9 Joules

Electric and LPG	=	9.75	9.75	9.75
Kerosene	=	8.00	8.00	8.00

For 1976, total number of urban households (standard housing) with electric cooking was estimated at 72,900, with LPG cooking at 330,000 and with kerosene cooking at 617,000, based on Census of Housing saturation data for 1972. Energy consumption per household for LPG is obtained from domestic LPG sales in 1972 and the number of households using LPG that year. For kerosene, see next page.

*An explanation of terms used in the Fuel Mix Table is presented in the following section.

Table B.3-13

FUEL MIX TABLE

Sector: Urban "Pueblo Joven"

End Use: Cooking

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Kerosene	1.0	0.4	0.4	4.0	0.4	8.5	1.0	0.4	25.6
TOTAL FUEL DEMAND, D, 10 ¹⁵ Joules			4.0			8.5			25.6
BASIS: (10 ³ Households)	200.			425.			1280.		
SATURATION, S,	1.0			1.0			1.0		
UNIT BASIC DEMAND, E _u 10 ⁹ Joules	8.0			8.0			8.0		

The amount of kerosene purchased per household was estimated at 0.5 gallon per day, of which 75% was assumed to be for cooking, 25% for light and other uses.

Table B.3-14

FUEL MIX TABLE

Sector: Rural Households

End Use: Cooking

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Electricity									
Kerosene	0.13	0.40	6.3	0.15	0.4	8.7	0.50	0.4	27.0
Firewood	0.74	0.10	138.0	0.75	0.10	174.0	0.45	0.10	97.2
Other (Dung and Peat)	0.13	0.10	24.0	0.10	0.10	23.2	0.05	0.10	10.8
TOTAL FUEL DEMAND, D,									
10^{15} Joules			168.3			205.9			135.0
BASIS: (10^3 Households)	2320.4			2900.			2700.		
SATURATION, S,	1.0			1.0			1.0		
UNIT BASIC DEMAND, E_u									
10^9 Joules	8.0			8.0			8.0		

The total number of rural households with kerosene cooking was estimated at 314,000; assuming total households using kerosene grow at 5 percent per year from 1972, the number in rural areas is obtained as a difference.

Table B.3-15

FUEL MIX TABLE

Sector: Urban & Rural Households
End Use: Lighting

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Electricity	0.35	1.0	0.86	0.40	1.0	1.35	0.63	1.0	3.18
Kerosene	0.46	0.2	5.63	0.45	0.2	7.62	0.37	0.2	9.32
Other	0.19	-	-	0.15	-	-	-	-	-
TOTAL FUEL DEMAND, D,									
10^{15} Joules			6.49			8.97			12.50
BASIS: (10^3 Households)	3541.2			4905.			7305.		
SATURATION, S,	1.00			1.00			1.00		
UNIT BASIC DEMAND, E_u									
10^9 Joules	0.69			0.69			0.69		

The consumption of kerosene for lighting is obtained as a difference between total kerosene sales to the sector and kerosene used for cooking.

Table B.3-16

FUEL MIX TABLE

Sector: Urban Households
End Use: Appliances

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Electricity	0.66	1.0	5.22	0.70	1.0	9.11	1.00	1.0	29.67
TOTAL FUEL DEMAND, D, 10 ¹⁵ Joules			5.22			9.11			29.67
BASIS: (10 ³ Households)	1220.8			2005.			4605.		
SATURATION, S,	0.66			0.70			1.0		
UNIT BASIC DEMAND, E_u 10 ⁹ Joules	6.5			6.5			6.5		

Obtained as a balance of electricity sales to residential customers for 1976. Projection allows for penetration of phantom appliances and other unspecified demands.

2.2.3 Energy Demand and Fuel Mix Analysis.* For the purpose of energy resource and technology assessment, it is necessary to develop projections of energy demands in a detailed or disaggregated manner. This approach is required in order to evaluate technologies that may apply to very specific end uses. To evaluate the use of a biomass-derived fuel for cooking, for example, the projected growth of this end use must be exhibited in the reference system.

It is recognized that projections made in this disaggregated manner may well underestimate the total energy demand in the future because of unanticipated new uses of energy. Since the technologies employed for such uses obviously cannot be defined, it is not, in general, necessary to reflect these uses in the reference systems. It is felt, however, that such demands are more likely to involve electrical energy than other energy forms. To reflect this impact on the supply systems, several undefined electrical demands can be included in the residential and commercial miscellaneous electric categories (by postulating phantom appliances and demands) and in the demand category for industrial miscellaneous process heat.

The projections of energy demands and the fuel mix for the reference years can be developed on worksheets, as shown in the following pages. It is useful to define several parameters. These are:

Fuel Demand, D_i = The quantity of a fuel, ** i, actually consumed in a specific demand category, such as space heating, automotive transport, or aluminum production.

Total Fuel Demand, D = The total fuel required to satisfy the requirements of a specific demand category. Electricity is considered as a fuel in this sense and $D = \sum_i D_i$.

Relative Effectiveness, e_i = The relative effectiveness with which fuel, i is used in a demand category. This parameter depends on the utilization technology employed.

Basic Energy Demand, E = The amount of energy that would be required in a specific demand category, assuming a relative effectiveness, e_i , of 100% for each fuel employed. Thus, for a given demand category i, where quantities of fuels, D_i , are consumed with actual Relative Effectiveness, e_i , $E = \sum_i e_i D_i$.

Degree of Saturation, S = The fraction of the potential demand for a particular energy use actually being fulfilled at a given time, for example, if 95% of all households have refrigerators, and potentially all houses can have one refrigerator, $S = 0.95$.

* Taken with modification from M. Beller, Ed. "Sourcebook for Energy Assessment", BNL-50483, Dec. 1975.

** Fuel as used in this sense includes electricity.

Saturated Basic Energy Demand = The Basic Energy Demand that would exist in a category if there was 100% saturation, = E/S .

Unit Basic Energy Demand, E_u = The Basic Energy Demand per unit, e.g., per household, per lb^u of Al produced, etc.

Fuel Fraction, f_i = fraction of the Saturated Basic Energy Demand that is satisfied by using the i'th fuel.

$$f_i = \frac{e_i D_i}{E/S} \quad \text{and} \quad \sum_i f_i = S$$

The procedure for developing the fuel mix projection in a given demand category begins with the definition of the base year mix. The methodology described above leads to estimates of the basic Energy Demand for each demand category in the reference year of interest.

The Basic Energy Demand derived in this manner is independent of the fuels employed to satisfy the demand and is projected into the future on the basis outlined above, including any increased saturation that may be postulated. In categories where a unit basic demand is defined, it is used as the basis for the projection and, in most cases, is held constant over all reference years. By specifying the Fuel Fractions, f_i , and Relative Effectiveness, e_i , the Fuel Demands, D_i are derived from the basic energy demands for each future reference year. Thus the fuel mix is defined.

2.2.4 Alternative Projection. This section presents an alternative growth pattern for the residential sector projecting energy demands without further penetration of kerosene into rural areas. There is no shortage of firewood in these areas, and the total number of rural household stabilizes at a figure only about 25 percent above the present total due to rural to urban migration. The price of kerosene in these isolated areas is set by middlemen and is very high compared with the government subsidized prices at urban outlets. Any increase in kerosene price (by partially lifting the subsidy) would most certainly have a large impact on the price in the rural areas. The Reference Case is altered by lowering the fraction of rural households using kerosene in 2000 from 0.50 to 0.15; firewood and other noncommercial fuels make up the difference.

Another perturbation of the reference projection analyzed here is to increase the proportion of standard urban households using LPG for cooking from 0.30 to 0.36 in 1985, and from 0.30 to 0.45 in 2000, replacing kerosene. Taking into consideration the 50 percent higher end-use efficiency assumed for LPG stoves (albeit a larger unit basic energy demand), this fuel switch results in a total savings of petroleum products to this sector. Table B.3-17 summarizes the energy implications of this alternative projection.

Table B.3-17

Residential and Commercial Energy Demands, Alternative Projection
(10^{15} joules)

	1976	1985	2000	Annual Growth Rates	
				1976-1985	1985-2000
Electric	9.39	16.58	52.73	6.5%	7.7%
Kerosene	28.27	41.88	62.97	4.5%	2.8%
LPG	5.35	9.24	24.30	6.3%	6.7%
Firewood	138.00	174.00	162.00	2.6%	-0.4%
Other	24.00	23.00	21.60	0	-0.4%

2.3 Industrial Energy Use

Energy used in the industrial sector is primarily in the form of petroleum fuels for process heating and steam raising, and electricity for electrolytic processes, electric furnaces, and prime movers.⁸ Some industrial sector electrical demand is satisfied by self-generated power at industrial sites (autoproduktors), requiring diesel fuel and kerosene for diesel generators, and gas turbines and residual fuel for conventional steam-electric power plants. At present, coal is not used in the industrial sector, with the exception of imported coke used in the steel and non-ferrous subsectors. A very small amount of natural gas is used in the operation of the Talara refinery and associated urea plant. Lubricants, asphalts, and other petroleum-based, "non-energy" uses amounted to 4.6×10^{15} joules in 1976.

Table B.3-18 summarizes energy consumption in 1976 in the major energy-consuming industrial subsectors. Brief descriptions follow below.

Table B.3-18

Selected Sectoral Energy Consumption, 1976
(10^{15} joules)

	<u>Electricity</u>	<u>Petroleum</u>	<u>Coal, Coke</u>	<u>Total</u>
Mining & Non-Ferrous Metals	7.05	20.24	1.58	28.87
<u>Industry</u>				
Iron & Steel	0.724	1.809	6.042	8.575
Cement	0.921	9.162	0	10.083
Oil Refining	0.52	10.50	0	11.02
Fertilizers	0.58	5.29	0	5.87

Source: Ref. B.3-8

Mining and Non-ferrous Metals. Energy consumption for this major subsector amounted to about 29×10^{15} joules in 1976, of which 24 percent was in the form of electricity for electric furnaces, electrolytic processes, and prime movers; 70 percent in the form of petroleum-based fuels; and about 5 percent in the form of coke for smelting operations.

Petroleum-based fuels	20.2×10^{15} joules
Coke	1.6×10^{15} joules
Electricity	1958×10^6 kwh/year

Oil Refining. The total energy used by this subsector in 1976 is estimated to be 11.02×10^{15} joules, of which almost 5 percent was consumed as electricity for motor drive and the balance as petroleum-derived fuels for process heat, steam raising, and electricity generation. A minor amount of natural gas is used in the Talara area for plant operations. Energy consumption is as follows:

Petroleum-based fuels	=	10.55×10^{15} joules
Electricity	=	144.6×10^6 kwh/year

This energy consumption corresponds to a refinery throughput of about 100,000 barrels per day.

Cement. The total energy used by this subsector in 1976 is estimated to be 10.1×10^{15} joules, of which 9 percent was consumed as electricity (mainly in crushing and grinding rocks and clinker) and 81 percent as petroleum-based fuels for the kilns.

Fuels	=	9.20×10^{15} joules
Electricity	=	256.90×10^6 kwh/year

The corresponding cement production was 1.97 million metric tons.

Iron and Steel. The total energy used by this subsector in 1976 is estimated to be 8.6×10^{15} joules, of which about 8 percent was consumed as electricity (all hydroelectric), 21 percent as petroleum-based fuels, and over 70 percent as coke for the blast furnace at Chimbote. All the coke was imported in 1976. The petroleum-based fuels are used in soaking pits, reheat and annealing furnaces (about 88 percent), and the balance is injected into the blast furnace (about 12 percent). Energy consumption in 1976 was as follows:

Petroleum-based fuels	273×10^3 barrels
Coke	200,000 tons
Electricity	201×10^6 kwh/year

The corresponding steel production was 360,000 tons.

Fertilizers. The total energy used by this subsector in 1976 is estimated to be 5.9×10^{15} joules, of which about 10 percent was consumed as

electricity and the balance as petroleum-derived fuels. Electricity is used in this subsector for conventional uses such as motor drives and blenders and the production of ammonium nitrate via an electrolytic route at the Cachimayo plant. Hydrogen for the ammonia plant is produced by the electrolysis of water, and nitrogen from an air separation plant. Nitric acid is also produced by an electric-arc process. The urea plant at Talara uses about 17 million cubic feet per day of natural gas for feedstock fuel and electricity generation. Total energy use is estimated as follows:

Natural gas and petroleum-based fuels	5.29×10^{10} joules
Electricity	161×10^6 kwh/year

Other Industries. Industries other than those described above consume petroleum-based fuels and electricity for conventional applications such as process heat and prime movers. Use of coal is unreported and is estimated at 3.6×10^{15} joules.

2.4 Industrial Energy Reference Projection

One basis for energy demand projections in the industrial sector is an estimate of future capacity derived from expansion plans in the industries under consideration. A hypothetical calculation of energy demand in 1985 and 2000, assuming growth at capacity, was made in the Report on Industrial Sector Demand.¹⁰ The reference projection, however, takes into account the economic considerations discussed in Section 3.0, and scales down the energy demand assuming full capacity. The economic considerations used to adjust these figures are outlined below.

2.4.1 Mining and non-ferrous metal (including mining of iron ore).

A growth rate of 6.7 percent is assumed to 1985, in accord with Instituto Nacional de Planificacion (INP) estimates of economic activity in this sector.¹¹ It reflects the low copper prices (compared to the early to mid-1970's) prevalent over the period. Growth in the 1985-2000 period is projected to average 4.0 percent per annum, also in accordance with INP estimates. This lower figure reflects a slowdown in capacity expansion during the period.

Among the new plants planned for this sector is MineroPeru's Ilo refinery with a capacity of 300,000 MT/year of refined copper. MineroPeru's Cerro Verde mine will substantially increase minerals production, as will the new mine at Cuajone. Centromin's La Oroya metallurgical complex will include a lead smelter, copper smelter, zinc refinery, electrolytic refinery for copper and lead, extraction of gold, silver, and bismuth, as well as many associated metals and chemical products. These facilities are scheduled to be completed in 1990. The Antamina mine is scheduled to come into production by 1985, and contains proven reserves of over 120 million MT averaging 1.56 percent copper and 1.27 percent zinc with significant quantities of silver and molybdenum. The Cobriza and Michiquillay mines are also important, as is the new zinc refinery planned for Cajamarquilla, near Lima.

The development of a more complex mining sector brings about changes in the mix of fuels into the sector for the future reference years. The growth rates cited above have been applied to the total physical output, and the associated demands for petroleum products and electricity are presented in fuel mix Table B.3-19.

2.4.2 Steel. Steel is projected to grow at capacity during the entire 1976-2000 period (average growth rates of 11.2 percent per year for the period 1976-1985, and 9.0 percent per year between 1985 and 2000). The industry is presently operating at full capacity, but nevertheless far below demand. Despite planned expansion of SiderPeru's steel complex at Chimbote, demand is expected to outstrip domestic steel supply during the entire period under consideration.

2.4.3 Cement. Cement production is projected to grow rapidly during the 1976-1985 period. This is due to the fact that cement production in Peru is geared to export markets in Ecuador, Bolivia, and elsewhere and is thus not entirely affected by domestic economic trends. Cement energy consumption is therefore assumed to grow at a pace commensurate with capacity expansion, yielding average annual growth rates of 6.0 percent in 1976-85, and 4.4 percent in 1985-2000.

The cement industry consists of five companies, all owned by the government. Important facilities are Cementos Lima's plant at Atocongo, Cemento Pacasmayo in the north, which utilizes blast furnace slag from the nearby Chimbote Steel complex, Cemento Yura (near Arequipa), and Cemento Sur at Juliaca. Much of future growth in cement production is planned to consist of expansion of existing facilities.

2.4.4 Petrochemicals. Petrochemicals are projected to grow at capacity until 1985 (3.1 percent per year), as there should be enough demand to sustain this rate of growth and thereby replace imports. For 1985-2000, growth in petrochemical production is projected to average 3.7 percent per year, a figure consistent with projections of refined oil production.

To date, Peru has produced little in the way of petrochemicals. Ambitious plans for a major project at Bayovar, with an estimated capital investment requirement of \$2.4 billion, were drawn up several years ago. It now appears that it will not be possible to raise this amount of capital, which will mean delays and cutbacks in the scale of the project. It seems that the olefins and derivatives plants will be constructed, but that other plants will be postponed indefinitely.

2.4.5 Chemicals. Chemicals are very dependent on activity in the mining and metal processing sectors, obtaining many inputs and selling the most outputs to those sectors. Therefore, production is assumed to grow at a rate comparable to those in the mining and metal processing sectors: 5.6 percent per year from 1976-1985, and 3.5 percent per year 1985-2000.

Table B.3-19

FUEL MIX TABLE

Sector: Mining and Non-ferrous Metals

	1976			1985			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
DIRECT FUEL USE									
Petroleum for process heat	0.53	0.60	13.1	0.50	0.60	22.4	0.49	0.60	39.5
Electricity	0.47	1.00	7.1	0.50	1.00	13.5	0.51	1.00	24.7
TOTAL FUEL DEMAND, D,									
10^{15} Joules			20.2			35.9			63.2
BASIS: per annum growth rate						6.7%			4.0%
BASIC DEMAND, E_u	15.0			26.9			48.4		

Petroleum inputs to self-generated electricity are projected at 12.9×10^{15} joules in 1985 and 23.6×10^{15} joules in 2000. In 1976, this figure was 6.8×10^{15} joules. Coal consumption (1.6×10^{15} Joules in 1976) is allocated to "industrial coal consumption".

The energy consumption projections calculated here, based on Instituto Nacional de Planificacion economic growth rates, are 73-72 percent of the consumption at full capacity.

Among the important sources of chemicals is the La Oroya metallurgical complex, which produces about 70,000 MT/yr. of sulfuric acid. About 176,000 MT/yr. of acid is expected to come from the new zinc smelter at Cajamarquilla. About 96,000 MT/yr. of nitric acid is produced at the Cachimayo and Fertisa fertilizer plants, as well as some 32,000 tons/yr. of ammonia. Peru also produces hydrochloric acid, sodium hydroxide, and several other chemicals.

2.4.6 Fertilizer. Fertilizer production is projected to be held down by current stagnation in the agricultural sector. (Four percent per year average 1976-1985.) It is projected to rise during the 1985-2000 period to an average rate of 5.0 percent per year.

Important facilities include the PetroPeru urea plant at Talara, the state owned Cachimayo ammonium nitrate plant, and the Fertisa plant in Callao. There are plans for a major phosphatic fertilizer complex at Bayovar.

2.4.7 Oil Demand. The industries discussed above account for 57 percent of industrial oil use in 1976. Data obtained from officials at PetroPeru's Oficina de Planeamiento accounted for another 29 percent of 1976 oil use in industry. These data, and the economic considerations used to project them to 2000, are outlined below:

Fishing consumed 8.99×10^{15} joules of oil in 1976. Due to the current crisis in anchovy fishing, this consumption is projected to drop 2.7 percent per annum during 1976-85. From 1985-2000 consumption of oil is projected to grow at 2.5 percent per annum. This figure agrees with estimates of economic activity made by the INP.

Glass production is assumed to follow construction trends. Hence it is projected to remain constant in the period 1976-1985 at a level of 4.85×10^{15} joules. It is projected to grow at 5.5 percent per year during 1985-2000.

Food processing consumed 6.34×10^{15} joules of oil in 1976. It is projected to grow at 1 percent per year 1976-1985 due to stagnation in the agricultural sector and rise to a rate of 3.5 percent per year from 1985-2000. Textile production consumed 3.14×10^{15} joules of oil in 1976. It is projected to follow overall macroeconomic growth. (1.8 percent per year 1976-85, and 5 percent per year 1985-2000).

Paper manufacturing consumed 3.14×10^{15} joules of oil in 1976. It is projected to grow at 1 percent per year during 1976-1985, reflecting the effects of the current depression. From 1985 to 2000 oil consumption is projected to grow at 5 percent per year, along with a general economic recovery. Construction consumed 1.8×10^{15} joules of oil in 1976 and is projected to consume an average 0.66 percent per year less over the 1976-85 period, reflecting extremely depressed activity in the construction sector. Consumption is projected to increase between 1985 and 2000 at an annual rate of 5.5 percent per year. Other industrial activities accounted for the remaining

Table B.3-20

Summary of Industrial Energy Demand Projections

(10¹⁵ joules)

SECTORS	1976			1985			2000		
	COAL	OIL	ELEC	COAL	OIL	ELEC	COAL	OIL	ELEC
Mining & non-ferrous	1.6	19.9	7.1	2.8	35.3	13.5	5.1	63.1	24.7
Steel	6.0	1.8	.7	15.6	4.7	1.9	56.7	17.0	6.8
Cement	-	9.2	.9	-	15.4	1.7	-	29.0	3.4
Petrochemicals	-	.2	.1	-	.4	.1	-	.6	.1
Chemicals	-	1.5	1.0	-	2.5	1.6	-	4.2	2.7
Fertilizers	-	5.3	.6	-	7.5	.8	-	15.6	1.7
Fisheries	-	9.0	n.a.	-	7.0	n.a.	-	10.1	n.a.
Glass	-	4.9	n.a.	-	4.9	n.a.	-	10.9	n.a.
Food Processing	-	6.3	n.a.	-	6.9	n.a.	-	11.6	n.a.
Textiles	-	3.1	n.a.	-	3.7	n.a.	-	7.7	n.a.
Paper	-	3.1	n.a.	-	3.4	n.a.	-	7.1	n.a.
Construction	-	1.8	n.a.	-	1.7	n.a.	-	3.8	n.a.
Others	-	20.6	3.9	-	22.5	5.4	-	55.2	12.9
Totals*	7.6	86.7	14.3	18.4	115.9	25.0	61.8	235.9	52.3

*Totals may not add due to rounding

Table B.3-21

Petroleum Use in Industry

	1976	1985 (10 ¹⁵	2000 Joules)
Petroleum to Mining Sector	19.9	35.3	63.1
to Electricity ^a	6.8	12.9	23.6
to Direct Uses	13.1	22.4	39.5
Petroleum to other Industries	66.9	80.6	172.8
to Electricity ^a	11.8	15.6	23.7
to Direct Uses	55.1	65.0	149.1
Total	86.8	115.9	235.9

^a Refers to self-generation of electricity ("autoproductores")

19.77×10^{10} joules of oil consumed (14 percent of the total to industry) in the sector in 1976. This amount is projected to grow at an average rate of 1 percent per year for 1976-1985, and 5 percent per year from 1985 to 2000.

2.4.8 Electricity Demand. The industries for which capacity expansion plans were available accounted for over 70 percent of industrial electricity consumption in 1976 (16.7×10^{15} joules). No breakdown of the remaining 4.3×10^{15} joules was available. As in the case of industrial oil consumption, demand projections based on 100 percent of capacity expansion planned were adjusted on the basis of economic and capacity factor considerations. (See "Oil Demand" Section above for more detailed explanation.) The remainder was projected to grow at 3.6 percent per year 1976-1985. This seemingly low figure is pulled down by the poor performance of the manufacturing sector at the beginning of the period and allows for 5 percent growth with economic recovery in the early 1980's. The growth rate in electricity consumption for 1985-2000 is 6 percent per year.

2.4.9 Coal Demand. Coal is little used in Peru, the only industrial sectors utilizing it being steel, mining, and non-ferrous metals. Reference projections were based on overall growth rates for these industries, assuming that the fuel mix remains constant. One should bear in mind, however, that exploitation of the Alto Chicama coal deposits, if feasible, could induce a shift toward coal in the industrial sector.

The projected demands for all fuels in industry are summarized in Table B.3-20. These energy demands show total petroleum inputs to industrial subsectors. For purposes of the Reference Energy Systems, they must be broken down between oil for direct uses and oil for self-generation of electricity (autoproduktores). Table B.3-21 shows an estimate breakdown for all reference years.

2.5 Transportation Energy Use

This section first presents the energy consumption by transport mode in 1976.¹² It thus presents the principal assumptions used in preparing the reference projection. It also includes an alternative view incorporating the decrease in gasoline being experienced in 1978 due to the economic recession and recent fuel cost increases.

Table B.3-22 summarizes the energy consumption by mode for 1976, and Table B.3-23 presents the estimates of activity levels and energy intensities for that year. These figures are obtained from the analysis presented below.

Table B.3-22

Transportation Energy Consumption by Mode, 1976

(10¹⁵ joules)

<u>MODE</u>	<u>CONSUMPTION</u>	<u>% OF SECTORAL TOTAL</u>
Truck	44.2	40.1
Automobile	22.1	20.0
Air	13.6	12.3
Ship	13.5	12.3
Bus	15.0	13.6
Railroad	1.9	1.7
Total	110.3	100.0

Table B.3-23

Transportation Activity Levels and Energy Intensity by Mode

<u>MODE</u>	<u>Activity Unit</u>	<u>1976 Activity Level x10⁹</u>	<u>Energy Intensity Joules x 10⁶ Activity Unit</u>
Automobile	Vehicle-Km	3.25	6.65
Motorcycle	Vehicle-Km	0.52	0.94
Bus	Passenger-Km	14.97	1.00
Truck (Freight)	Ton-Km	5.86	6.30
Truck (Non-Freight)	Vehicle-Km	0.94	7.77
Rail (Freight)	Ton-Km	1.03	1.10
Rail (Passenger)	Passenger-Km	0.53	1.57
Air	Passenger-Km	1.36	N.A.
Ship	Ton-Km	4.71	N.A.

Automobiles. Estimates made during the assessment were 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. We estimate that average energy intensity for automobiles in Peru is 6.65×10 joules per vehicle-kilometer, corresponding to about 20 Km per gallon. The automobile fleet has a nominal fuel efficiency of about 30 Km per gallon, but maintenance, road condition, and congestion make the lower figure more acceptable.

Buses. In 1976, there were approximately 23,000 buses in Peru. The Plan Director de Transporte (PDT) estimates that inter-city passenger traffic was 4.27×10^9 passenger-kilometers.¹³ There is no breakdown in the plan between buses and other automotive travel. The Metro Lima study¹⁴ 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 in 1976 public transport in other urban centers amounted to 1.64×10^9 passenger-kilometers.

It was assumed that 10 percent of intercity passenger-kilometers are by automobile. Approximately 12 percent of public transport vehicles in urban centers are colectivos (public taxicabs along fixed routes). Average passengers per colectivo, however, can be assumed to be approximately 10 percent of public transport passenger-kilometers in cities. This has been allowed for in the calculation of bus passenger-kilometers in Table B.3-24.

Table B.3-24

Bus Passenger-Kilometers, 1976 ($\times 10^9$)

Intercity	3.84
Lima	9.51
Other Urban	<u>1.62</u>
Total	14.97×10^9 passenger kms.

Source: Ref. B.3-14

A fairly high intensity value of 1.0×10^6 joules passenger-kilometer was assumed, considering the predominantly urban concentration of buses (two-thirds of passenger-kilometers are in urban areas) and the poor road surface on inter-city routes.

Trucks (Freight). In 1976, there were approximately 61,000 freight trucks in Peru. At present, about 70 percent of the trucks use gasoline and 30 percent, diesel fuel. The trend toward dieselization will probably reverse these proportions in the near future. Trucks are virtually the only mode of freight haulage for the agricultural and manufacturing sectors, serving the large urban centers along the coast of Peru via the Pan American Highway.

The Ministry of Transport and Communications (MOTC)¹⁵ estimates road freight in 1976 at 5.86×10^6 ton-kilometers. On the assumption that a negligible amount of freight moved by bus, this figure is accepted as the freight movement by the estimated fleet (61,000). Since information about urban freight movements does not exist in Peru, this may underestimate total freight movement. The high level of energy intensity for freight trucks (6.30×10^6 joule per ton-kilometer) reflects poor road conditions and difficult terrain on intercity routes.

Truck (Non-freight). This is assumed to be predominantly movement confined to light vans. On the assumption that the entire light van population of 62,000 is engaged 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 9.4×10^6 vehicle-kilometers per year were covered by this type of vehicle.

Motorcycles. It is estimated that the average motorcycle travels 11,064 km/yr and has an energy intensity of 0.94×10^6 joules vehicle-kilometer.

Rail (Freight). Peru has two major railroad systems: the central one connects Lima with the mining centers to the interior and a southern one links Cuzco with the city of Puno on Lake Titicaca, which then connects to the Pacific Ocean port of Matarani. In addition to carrying Peruvian minerals, the southern rail system is the main access of landlocked Bolivian trade to oceangoing vessels. Beyond these two major systems, there are four small railroads linking mines relatively near the coast to shipping ports.

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. intercity experience. The difficult terrain justifies this high intensity.

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

The energy intensity used here is between the U.S. experience in the mid-1970s 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 in the U.S. or the United Kingdom, but higher load factors significantly reduce the intensity per passenger-kilometer.

Air. Since Peru has relatively few roads and formidable natural barriers to ground transportation, domestic air transportation plays a crucial role in the country's communications. 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.

Maritime. The dominant sectors in shipping are international freight (70 percent of total tons carried) and maritime intercoastal freight (26 percent of totals tons). Intercoastal shipping consists mainly of iron ore shipped from the mines in the Nazca area to the Chimbote steel works, and the shipping of crude oil from the north to refineries in the Lima area. Lake Titicaca shipping is linked with Bolivian trade, and fluvial shipping is limited to the large river systems of the eastern Sierra and Selva, which are not densely inhabited.

The PDT indicates 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. A figure of 0.46×10^6 joules ton-kilometer was applied to the Peruvian situation.

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

The estimates for this mode are based directly on bunker sales of diesel, intermediate fuel oil, and bunker "c" given by Petroperu.

2.6 Transportation Energy Reference Projection

The growth rates of the transportation activity levels for all modes that have been used in the reference projection are presented in Table B.3-25. Their derivation is outlined below. Table B.3-26 summarizes the activity levels by mode for 1985 and 2000. Total oil consumption grows from 110×10^{15} joules in 1976, to 156.5×10^{15} joules in 1985, and to 350.9×10^{15} joules in 2000, representing a 1976-85 growth rate of 4.0 percent, and a 1985-2000 growth rate of 5.5 percent. Table B.3-27 presents the energy projections by transport mode for all reference years.

Table B.3-25

Estimated Growth Rates of Transportation Activity Level
by Mode Between 1976 and 2000

<u>MODE</u>	<u>AVERAGE ANNUAL GROWTH RATE (%)</u>	
	<u>1976-1985</u>	<u>1985-2000</u>
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 B.3-26

Transportation Activity Level Projections 1976-2000
(x 10⁹)

MODE	Activity Unit	1985	2000
Automobile	Vehicle-Km	4.24	8.81
Motorcycle	Vehicle-Km	0.68	1.41
Bus	Passenger-Km	27.73	63.98
Truck (Freight)	Ton-Km	7.65	19.67
Truck (Non-Freight)	Vehicle-Km	1.23	3.16
Rail (Freight)	Ton-Km	1.47	2.65
Rail (Passenger)	Passenger-Km	0.69	1.43
Air	Passenger-Km	1.97	3.19
Ship	Ton-Km	7.96	19.08

Table B.3-27

Peru Energy Consumption Transport Sector by Mode

Mode	10 ¹⁵ Joules		
	1976	1985	2000
Truck	44.2	57.7	148.4
Automobile	22.1	28.8	59.9
Air	13.6	19.4	34.9
Ship	13.5	20.1	38.9
Bus	15.0	27.8	63.9
Rail	1.9	2.7	4.9
Total	110.3	156.5	350.9

2.6.1 Automobile. Three factors militate against rapid growth of automobile passenger-kilometers in the near term (to 1985): (1) economic difficulties in the country; (2) mounting urban congestion in Lima; and (3) the poor condition of roads outside Lima.

A 3 percent growth rate for the period, which is the Petroperu forecast for gasoline sales for this period, therefore seems reasonable; it appears unlikely that all of these difficulties will be surmounted by 1985. After 1985, the growth in economic activity assumed in this analysis will raise the growth rate of automobile travel. A 5 percent growth for that period is therefore reasonable.

2.6.2 Bus. Urban Lima is expanding very rapidly; it is expected that passenger-kilometers in the capital will increase at an average annual rate exceeding 8 percent, although the growth rate is expected to be less over the period 1985-2000. Intercity 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 and, seasonally, by road; some passenger traffic will be generated on these essentially new links.

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

2.6.4 Truck (Non-Freight). This is also related to industrial growth with growth rates similar to those for freight trucking.

2.6.5 Rail (Freight). The growth rate projected for rail freight (4.0 percent) approximates that calculated in the PDT (3.64 percent).

2.6.6 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, intercity passenger travel by rail should grow faster post-1985.

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

2.6.8 Maritime. The PDT forecasts an annual growth of 9.7 percent 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.

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

2.6.9 Alternative Projection. The choice of 1976 as the historical base year for this assessment has generally proved to be adequate, and most importantly, that year was largely devoid of the income effects of the current economic stagnation on energy demand. Since 1976, however, large price increases have occurred, especially for gasoline. The price of high octane gasoline rose in the period January 1976 to May 1978 from 30 soles per gallon to 145 soles per gallon (in the same period the sol was devalued vis-a-vis the dollar by a factor of three). The reference projection has thus ignored the effect of the price increase, yet it is reasonable to believe that these increases will permanently affect patterns of gasoline consumption.

Figure B.3-3 shows gasoline sales and the successive retail price increases for the 1975-1978 period that result in a drop of 25 percent from 1975 levels. It is not possible to separate the impact of the economic stagnation from that of the price increase. An alternative projection based on estimated 1978 gasoline consumption levels that are predictably lower than the Reference Case is therefore presented below.

The following assumptions have been made: that an estimated 27 MBD (69.2×10^{15} joules) of gasoline will be sold in 1978; that bus consumption remains at 1976 levels (the increase in public transportation due to cutbacks in auto travel is offset by higher load factors and the lower economic activity); and that the drop in auto and truck gasoline consumption is evenly distributed. The 1978 energy figures are projected to 1985 and 2000 using the same growth rates as in the Reference Case. Table B.3-28 summarizes the alternative projection.

The alternative projection yields a total gasoline consumption for 1985 of 31.7 MBD , which comes very close to Petroperu's estimate of 32.1 MDB .¹⁶ A comparison with the Reference Case projection (all other transport modes are left unchanged), shows that the alternative projection is lower by 26.6×10^{15} joules in 1985 and by 63.0×10^{15} joules in 2000, or 17 percent and 18 percent, respectively.

FIG B.3-3 GASOLINE SALES DURING PERIOD 1975-1978

Table B.3-28

Transportation Sector, Alternative Projection

	1976 RES		1978 est.		1985 Alt. Proj.		2000 Alt. Proj.	
	Percent		Percent		Percent		Percent	
	Gasoline		Gasoline		Gasoline		Gasoline	
Auto	22.1	100	16.1	100	19.8	100	41.2	NA
Truck	44.2	73	35.6	73	43.7	60	112.4	NA
Bus	<u>15.0</u>	100	<u>15.0</u>	100	<u>24.2</u>	75	<u>55.6</u>	NA
	81.3		66.7		87.7		209.2	

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APPENDIX C

ENERGY CONVERSION TABLES

ENERGY CONVERSION TABLES

Energy Resource	Unit	Joules x 10 ⁶
Crude Oil	Barrel	6,120
Petroleum Products		
LP Gas (propane/butane)	Barrel	4,230
Gasoline	Barrel	5,540
Kerosene	Barrel	5,980
Aviation Fuels	Barrel	5,540
Distillate (diesel, gas oil, heating oil, no. 2 oil)	Barrel	6,145
Residual (heavy oil, bunker- fuel, no. 5-6)	Barrel	6,630
Barrel of Oil Equivalent		6,120
Coal		
Bituminous		
U.S. Average	Metric Tons	27,900
Peru	Metric Tons	25,100-31,400
Lignite		
U.S.	Metric Tons	16,300
Peru		11,300-18,000
Firewood	Metric Tons	16,300-22,000 ^a
Bagasse	Metric Tons	11,000 ^a
Natural Gas	Cubic Meters	37,240
	Cubic Foot	1,087

MISCELLANEOUS CONVERSIONS

Volume	1 Barrel	=42 gallons (U.S.)
	1 Gallon	=3.785 liters
	1 Cubic Foot	=28.32 liters
	1 M ³	=35.31 cubic feet
	1 Barrel	=159 liters
	1 MCF (10 ³ cu.ft.)	=28.32M ³
Energy	1 KWHR	=3.3 million joules
	1 BTU	=1055 joules
	1 KCAL	=4184 joules
Other	1 Barrel ^b Per Day	=365 BBLS (per year)
	1 MBDOE ^b	=2.23 EJ (per year)

^a Approximate value or range

^b MBDOE: million barrels per day oil equivalent, used frequently in energy statistics.

MISCELLANEOUS CONVERSIONS (cont'd.)

kilo	$=10^3$ (K)
mega	$=10^6$ (M)
giga	$=10^9$ (G)
tera	$=10^{12}$ (T)
peta	$=10^{15}$ (P)
exa	$=10^{18}$ (E)

APPENDIX D

SUMMARY OF PERUVIAN ECONOMIC DEVELOPMENT PLANS

APPENDIX D

SUMMARY OF PERUVIAN ECONOMIC DEVELOPMENT PLANS

I. INTRODUCTION

The Instituto Nacional de Planificacion (INP) has produced a working paper in which the principal goals and characteristics of the long-term (1978-1990) economic plan are laid out.¹ This paper is qualitative in nature; emphasis has been placed on defining the direction and type of growth desired rather than translating these trends into concrete quantities.

The paper consists of three main sections. The first discusses the major problems of Peruvian development and examines important trends and processes in the economy. The second section discusses the ultimate goals of Peru's development effort, and the progress toward these goals that can be achieved by 1990. The third section contains a discussion of the concept of long-term economic development and its application to Peru.

II. PRINCIPAL GOALS OF PERUVIAN DEVELOPMENT PLANNING

The meaning of long-term development and the manner in which it is conceptualized by Peruvian planners is fundamental to an understanding of the implicit goals of the long-term plan. The most significant aspect of this conceptualization is that Peruvian planners reject a continuation of past development trends. While avoiding a sudden break (with its attendant costs) with past development processes, a gradual redirection is seen as necessary. The main features of this redirection are:

1. Orientation of the productive sector toward internal demand in order to reduce the influence of external factors.
2. Efficient utilization of internal sources and the development of technologies appropriate to these resources.
3. Minimization of Peru's role as a primary exporter, while expanding exports of manufactured and processed goods. LAFTA (Latin America Free Trade Area) and the Andean Common market are seen as useful means to this end, as well as the goal of increased economic integration with other Latin American countries.
4. Emphasis on rural development, especially in agriculture.
5. Increased emphasis on the spatial aspects of development in order to bring the interior of the country to a level of development comparable to that of the coast, where development has previously been concentrated.

These characteristics of growth in Peru will be instrumental in achieving the principal goals of the long-term plan. These goals are discussed below:

1. Increase national product substantially at a rate at least as high as past trends in per capita product. Over the past 25 years, Gross Domestic Product has increased at an average annual rate of 5%, while GDP per capita has increased at 2.25% annually.
2. Reduce population growth. The above issue of per capita income is closely related to population growth. Peru's population (currently 16.8 million) is growing at an average annual rate of close to 3%. Should this pace continue unabated, the population in 1990 will be 23.3 million. Hence, a major goal of Peruvian planning is to reduce population growth as much as possible so as not to outstrip growth in GDP and food production.
3. Increase production of food. Malnutrition is currently a problem in many areas of Peru. Food shortages have inflationary effects and food imports represent a drain on the limited supply of foreign exchange.
4. Income distribution. A more equal distribution of income is an important goal of the plan. Over the past two decades, the upper income classes have increased their share of national income substantially, a trend which should be reversed. Narrowing of regional inequities (particularly Lima vis-a-vis the Sierra) is also an objective of the plan.
5. Reduce disparities in regional growth rates. This is considered to be a very important, although to some extent intractable, problem. In 1972, 50% of families lived in rural areas, but only 25% of the national income went to these families. Moreover, 80% of these rural families live in the Sierra and have an average annual income of 40% of the national average. Efforts toward drawing the marginal rural population into the money economy and increasing its productivity are needed. Improvement in rural areas will have the effect of reducing rural-urban migration.
6. Elimination of under and unemployment. This is very important, both in terms of total national product and regional inequalities. Rural and marginal urban populations are currently plagued with low productivity and high rates of unemployment.

III. THE PRODUCTIVE STRUCTURE OF THE ECONOMY

Between 1950 and 1977, GDP grew at an average annual rate of 5.01%, while per capita GDP grew at 2.25%. The long-term plan calls for an average GDP growth of 5.08% over the 1977-90 period. The current economic crisis has reduced the planned 1977-82 annual growth rate to 2.52%. To

make up for this low rate at the beginning of the planning period, average growth in GDP of 6.71% per annum is called for from 1983-1990.

No sectoral breakdown of GDP growth is included in the long-term economic plan. There is, however, a sectoral breakdown contained in the Medium Term Plan² covering the years 1977-82. Table 1 contains a summary of these projections.

It is clear that the agricultural sector is not expected to grow rapidly over the next five years. However, if the planned goals are achieved, Peru will be able to start cutting agricultural imports by 1982.

Mining, while showing extremely high growth in 1977 and 1978, is not planned to continue growth at this pace. Rather, the leading sectors in the early 1980s are expected to be manufacturing and construction, as they rebound from their present extremely depressed state. Mining will, however, continue to be a very important sector, supplying a much needed flow of foreign exchange. Fishing, accounting for a relatively small share of the total, will show almost no growth over the 1976-82 period.

Also of interest is the decreasing share of government in the GDP. This reflects a gradual backing off of the state from its current highly active role in the economy.

State investments planned to date for the 1978 - 1990 period are outlined in the long-term plan. The sectoral split of these investments is shown in Table 2.

Approximately 60% of this investment is planned to be financed by internal resources, with the remainder being financed externally.

The geographical distribution of state investment is discussed in the long-term plan. Investments in northern regions (departments of Tumbes, Piura, Lambayeque, La Libertad, Ancash, Cajamarca, San Martin, and Amazonas) are concentrated in agriculture and industry, with some investments in fishing and hydrocarbons. However, nearly all investment in hydrocarbons will go to the eastern region (department of Loreto), with little other investment in that region. The majority of funds allocated to the central region (departments of Huanuco, Pasco, Lima, Junin, Huancavelica, Ica, and Ayacucho) are dedicated to mining and metallurgy, with some investment in hydrocarbons. Nearly all mining investment is concentrated in this region. Investment in the southern region (departments of Cusco, Apurimac, Arequipa, Madre de Dios, Puno, Moquegua and Tacna) is allocated mainly to agriculture, with some funds going to industry, fishing, and mining.

Table D-1

D-6

GROSS DOMESTIC PRODUCT BY SECTORS AS PROJECTED IN MEDIUM TERM PLAN

	<u>Millions of 1970 Soles</u>							<u>Percent Variation</u>					
	1976	1977	1978	1979	1980	1981	1982	77/76	78/77	79/78	80/79	81/80	82/81
GDP	<u>326,559</u>	<u>320,245</u>	<u>313,645</u>	<u>318,356</u>	<u>329,224</u>	<u>344,494</u>	<u>362,760</u>	<u>-1.0</u>	<u>-2.1</u>	<u>1.5</u>	<u>3.4</u>	<u>- 4.6</u>	<u>5.3</u>
Production of Goods	<u>169,724</u>	<u>166,547</u>	<u>164,558</u>	<u>167,480</u>	<u>174,272</u>	<u>183,355</u>	<u>194,367</u>	<u>-0.1</u>	<u>-1.2</u>	<u>1.8</u>	<u>4.1</u>	<u>5.2</u>	<u>6.0</u>
Agriculture	44,130	41,171	41,089	42,198	43,337	44,637	46,065	0.1	-0.2	2.7	2.7	3.0	3.2
Fishing	3,145	2,897	2,772	2,777	2,849	3,086	3,237	-7.9	-4.3	0.2	2.6	8.3	4.9
Mining	20,401	26,521	30,579	31,588	32,599	34,588	35,937	30.0	15.3	3.3	3.2	6.1	3.9
Manufacturing	83,966	79,684	74,983	75,358	78,372	83,074	89,720	-5.1	-5.9	0.5	4.0	6.0	8.0
Construction	18,082	16,274	15,135	15,559	17,115	17,970	19,408	-10.0	-7.0	2.8	10.0	5.0	8.0
Production of Services	<u>156,835</u>	<u>153,698</u>	<u>149,087</u>	<u>150,876</u>	<u>154,952</u>	<u>161,139</u>	<u>168,393</u>	<u>-2.0</u>	<u>-3.0</u>	<u>1.2</u>	<u>2.7</u>	<u>4.0</u>	<u>4.5</u>
Government	24,596	25,285	25,285	25,538	25,921	26,439	27,100	2.8	0.0	1.0	1.5	2.0	2.5
Housing	12,651	12,904	13,098	13,360	13,694	14,173	14,740	2.0	1.5	2.0	2.5	3.5	4.0
Others	119,588	115,509	110,704	111,978	115,337	120,527	126,553	-3.4	-4.2	1.2	3.0	4.5	5.0

Sources: 1976 Instituto Nacional de Estadisticas
 1972 Estimate from Instituto Nacional de Planificacion
 1978 - 82 INP projections.

Table D-2

Sectoral Split of Planned State Investment, 1978-1990

Agriculture	26.1%
Electricity	17.5
Transportation	11.4
Mining	9.9
Hydrocarbons (petroleum, gas, coal)	7.1
Housing	4.1
Education	3.8
Industries	3.1
Social Security	2.3
Fishing	2.3
Health	2.0
Tourism	1.8
Communications	1.1
Other	7.5
	100.0%

IV. THE INTERNATIONAL CONTEXT

The long-term plan makes it clear that Peruvian planners view past development in Peru as a process of "dependent capitalist development." Dependence on industrialized countries for capital goods and inputs is seen as a problem to be overcome over the next few decades. Equally important is Peru's dependence on export markets (a substantial percentage of GNP; approximately 10% in 1976). The instability of the international market in many primary goods (particularly copper, in Peru's case) has been a problem and Peru is seeking remedies for this situation. To date, efforts in this direction (such as a producer cartel in copper) have not resulted in great success. Diversification of exports is, and will continue to be, a major facet of government policy.

V. THE CURRENT CRISIS

The financial crisis of the past few years has resulted in a marked reduction in investment and growth together with high inflation. The decreased ability to import, as well as the decreased ability of the domestic market to provide a stimulus to production, has had a profound effect on long-term plans. International debt service has been a major cause of difficulties in this area, and will continue to be a problem for the next few years.

Plans call for gradual recovery of the economy in the short- and medium-term in order to achieve a stable self-sustaining pace of development in the long-term.

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APPENDIX E

MACROECONOMIC AND FINANCING PERSPECTIVES FOR PERU'S
ENERGY SUPPLY FACILITY INVESTMENT, 1978-2000

MACROECONOMIC AND FINANCING PERSPECTIVES FOR PERU'S
ENERGY SUPPLY FACILITY INVESTMENT, 1978-2000

1.0 INTRODUCTION

The Joint Peru-United States Energy Assessment analyzed several possible alternate strategies for energy development in Peru. These strategies balance energy demand requirements with potential energy resources and supply capabilities. A set of requirements for investment in energy supply facilities has been defined for each strategy (see Annex 10, "Capital and Labor Resources Required to Implement Selected Energy Futures for Peru"). The analysis in this Appendix is based on the supply facility investment requirements that are projected for the Reference Case. Although some variations could be expected if the facility requirements for one or another of the alternate strategies were examined, the differences would not be great enough to have a substantial effect on the results that are presented here. That is, this analysis attempts to place these investments and the attendant financing requirements into perspective with Peru's historical and projected economic development. These results provide the basis for the economic and financial observations that are given in Section 5.2 of the Main Report.

Briefly summarized, this analysis shows that energy supply facility investment and financing will be a primary factor in Peruvian energy and economic development through the year 2000. Excluding the capital costs of petroleum development, total capital costs to construct the energy supply facilities of the Reference Case are estimated (see Table 1) to be \$13,978 million (1978 dollars) over the period 1978-2000. This annual external debt for these capital costs will exceed \$2,909 million in the year 2000, and cumulative external debt service over the period 1978-2000 will be more than \$4,644 million. These sums are large by Peruvian standards, and they take on heightened importance in view of the recent problems of the Peruvian economy, particularly domestic investment requirements that exceed the economy's ability to generate sufficient savings, the fall of export earnings, and the increased reliance on external borrowings. However, the results of the assessment indicate that, if recent government economic and financial measures are successful, it should be possible to finance the capital requirements for energy supply within reasonable prospects for the country's development, and that the current difficulties may be only a problem over the near term.

Section 2 of this Appendix discusses the assumptions that underlie the analysis, including construction cost calculations (Section 2.1), procedures for estimating borrowing, interest-during-construction, and debt service (Section 2.2), and assumptions on interest rates, loan maturity, inflation and escalation, and the role of foreign borrowing (Section 2.3).

Section 3 presents the results of the investment and debt calculations. These results are discussed in the context of historical and projected macroeconomic and financial conditions in Peru, including comparisons to

overall growth capacity (Section 3.1), to growth in the utility and petroleum sectors (Section 3.2), and to other sectoral economic growth objectives (Section 3.3). Section 3.4 examines Peru's capacity to support and utilize energy investment, including domestic savings, foreign exchange effects, and infrastructure development. The last section (3.5) focuses on imports, external financing, and debt service.

This analysis has been limited to an examination of macroeconomic factors in the Peruvian economy. No attempt has been made to estimate costs and benefits or to project rates of return for specific projects. This is an extremely important step that should be taken after Peruvian officials have incorporated the assessment findings into specific program plans.

TABLE 1

CUMULATIVE CAPITAL REQUIREMENTS BY FACILITY GROUPING, 1978-2000,
TOTAL, % OF TOTAL, % DOMESTIC, (MILLION DOLLARS, JAN. 1978)

REFERENCE CASE

	Total	% Total Capital	% Domestic
Oil			
Exploration, Development, & Production	3211.150	23.0	33.0
Refining	1572.815	11.3	26.1
Pipelines	20.086	.1	30.0
Tankers, Barges, Trucks	277.660	2.0	24.9
Bulk Stations	47.068	.3	51.1
Others	221.944	1.6	28.0
Total Oil	5350.723	38.3	30.5
Gas			
Exploration, Development & Production	14.166	.1	25.5
Distribution	49.893	.4	40.0
Total Gas	64.058	.3	37.5
Coal			
Mining	119.828	.9	30.0
Transportation	3.179	0.0	16.1
Total Coal	123.007	.9	30.1
Electric Utilities			
Conventional Hydro	5512.779	39.4	32.2
Mini & Micro Hydro	110.672	.8	91.0
Combustion Turbine	196.901	1.4	20.8
Diesel	720.024	5.2	24.9
Other Oil & Gas Fueled	23.908	.2	29.2
Conventional Coal-Fired	448.460	3.2	26.1
Heat Recovery	27.862	.2	27.6
Other Generation	51.367	.4	25.5
Total Generation	7068.056	50.6	31.7
Transmission	782.341	5.6	39.8
Distribution	590.240	4.2	70.7
Total Utilities	8440.636	60.4	35.1
Total Energy Industry	13978.414	100.0	33.3

2.0 ASSUMPTIONS FOR THE CAPITAL COSTS AND DEBT CALCULATIONS FOR ENERGY SUPPLY FACILITY INVESTMENTS

2.1 Construction Costs

The Energy Supply Planning Model (ESPM) was used to estimate the cost, equipment, and manpower requirements for all facilities that are involved in the extraction, processing, conversion, and delivery of energy fuels and electricity. The model and engineering data base were modified to reflect contemporary (1978) Peruvian conditions. The ESPM was used to estimate the costs of the facilities required to implement the energy supply system in each strategy. In addition, separate calculations were made for import requirements and for domestically available inputs (see Section 1.3 and 3.5 of the Main Report and Annex 10 for the details). These cost figures and the related capital cost calculations form the basis for the projected investment requirements and debt calculations that are discussed in this Appendix. To minimize the uncertain effects of domestic inflation in Peru, all costs were converted to constant 1978 dollars for presentation (see Section 2.3 for additional details).

Note that none of these calculations treats facilities, systems, or equipment that consume energy; this discussion covers only the energy supply system. Thus, the estimated capital costs do not cover all costs of an energy strategy, since investments that affect energy consumption in the industrial, transportation, and commercial and residential sectors have not been included.

2.2 Interests During Construction, Borrowings, Debt, and Debt Service

The estimates of energy facility construction costs and schedules also permit calculation of interest and amortization elements for the related investment program. Total capital costs are then developed that include interest during construction, and borrowings for each facility. Debt accumulation, repayment, and interest charges can also be estimated. Annex 10 provides the procedure used in these calculations. The basic assumptions and estimates for Peru are given below.

Borrowings - Borrowings for a project occur yearly, as the funds are actually disbursed for construction expenditures. Inflation increases the cost of construction and thus raises the cost of funds that are borrowed each year. This analysis assumes that imported components in energy projects are supported by external borrowing (although there may actually be domestic funding of some imports and, on the other hand, direct foreign investment in otherwise purely domestic activities - see Section 2.3.1). The international rate of inflation was assumed to be 7%, and no other additional escalation factor was assumed. All final results were then deflated to constant 1978 dollars for comparison and interpretation.

Interest During Construction - Borrowings during the project construction period were charged interest which accrued to total borrowings and added to the total capital cost of the project. Interest was charged on the current value of borrowing, including the inflation elements for each

year, although all costs were deflated to 1978 dollars for presentation. The interest rate assumed on foreign borrowings was 8.5%; that for domestic borrowings was 0%.

Debt Service - At the completion of project construction an amortization schedule is calculated which repays the borrowings over a specified period while paying the given interest rate on the portion of the debt that remains outstanding. For domestic borrowings, the amortization period was assumed to be the useful economic life of the project; for foreign borrowings, the period was assumed to be fifteen years.

Beginning and End Point Effects - The cost calculations were made for projects which would be under construction during the period 1978-2000. Expenses for projects that were started prior to 1978 were approximated for construction costs after 1978, and thus investment figures for the initial years in the period of the Assessment may rise or fall because of these previous decisions on additions to capacity. However, the debt calculations do not include borrowings before 1978 on such facilities, nor do the debt service numbers account for pre-1978 borrowings. There are similar "end effects" for projects that are started by the year 2000 but not completed. However, estimates of these "end effects" were made by projecting facility requirements through the year 2010 for future years. As a result, some measurable portion of investment costs and borrowings near the year 2000 supports projects that will not be completed during the interval of the Assessment.

2.3 Interest Rates, Maturity, Inflation, and Escalation

Two sets of calculations were made for energy sector investments: those for imported components of the energy investments, and those for the domestically available share. Interest rate and maturity period assumptions were different for each category. The imported and domestic investment costs were then summed to give total costs.

2.3.1 Imports and Foreign Debt Calculation - Peru's balance of payments and foreign exchange and reserves difficulties in the recent past have dictated that external financing be sought for most of the imported materials, equipment, and manpower to support infrastructure investment projects. Though the possibility exists for direct foreign investment in Peru's energy facilities, it is very likely that, except for oil, most large energy supply facility investments will remain in the public sector.

For oil exploration, development, and production, Peru has continued to encourage direct investment by foreign oil companies. However, for this analysis it was not possible either to project future percentages of direct investment by foreign oil companies or to predict the arrangements under which foreign oil companies would share new discoveries and production with PetroPeru. Thus, for clarity and to avoid confusion, this analysis treats all oil exploration, development, and production investments as if they were made by Peru. This permits an approximation of foreign borrowings for all energy investments to be made by aggregating all import requirements and assuming that all of these are externally financed. An

alternate calculation was performed in which it was assumed that all imports for the petroleum sector were directly financed by foreign oil companies (or possibly oil revenues) and thus did not enter into debt calculations.

The potential sources of financing for energy development in Peru include bilateral, multilateral, and private institutions. The interest rates and loan maturities would in turn depend on political, economic, and project-specific considerations. Table 2 presents the recent history of Peruvian borrowings from private versus multilateral-bilateral creditors and shows the average interest rates and maturities for each. Table 3 indicates the same for recent public external borrowings by the Peruvian electric sector. This analysis assumes that future interest rates are more likely to be similar to those charged by commercial banks than had been the case in the past, and the portion of loans placed at the lower multilateral interest rates will decline somewhat from the current high level. On that basis, and given that most energy projects have long economic lives, an average 8.5 percent interest rate and 15 year maturity period have been assumed for external borrowings for the energy sector. Since the rate of world-wide inflation is assumed to be 7%, the real cost of foreign borrowing is still very low, which indicates that some level of bilateral/multilateral subsidy of energy development in Peru will continue.

2.3.2 Domestic Investment Calculations - For the domestic component of energy investment an interest rate has arbitrarily been set at 0 percent. This is neither an indication of the cost of money to the public sector nor an indication of the cost of raising money through taxes or debt financing. Rather, it permits the cost of domestic capital to reflect only construction costs. To allow for replacement charges, amortization is made over the economic life of each project. The final capital cost estimates (both domestic and foreign) are thus clearly understated, and provide a lower bound (or limit) for the analysis and interpretations. An alternative calculation was carried out using a 12 percent interest rate in order to indicate the cost of money if it were valued in terms of returns on other, high-yield investments in the Peruvian economy.

Inflation, Escalation, and Constant Dollar Calculations - In reality, market interest rates embody a rate of international inflation. A 7 percent rate of inflation has been assumed for the year 2000 as reflecting possible developed country lending conditions. Since the domestic portion of the costs was also calculated in dollars (to avoid the uncertain effects of the inflation of the sol), the 7 percent rate was used for both import and domestic calculations. This same rate was assumed for escalation in energy facility construction cost, although this is substantially less than recent levels for much of that sector. It can also be expected that domestic inflation in Peru will have widely varying effects across sectors and between equipment, materials, and manpower categories. To avoid distortions due to inflation, all of the results that are presented in the analysis were deflated back to 1978 dollars after the debt service calculations were performed. It should be noted that the interest and inflation assumptions together yield low (for imports) or negative (for domestic) real rates of interest and give a decided bias in favor of borrowing to finance energy supply facilities that have long economic lives.

TABLE 2
EXTERNAL PUBLIC DEBT - PERU, 1972-1977

	1972	1973	1974	1975	1976	1977
Total Debt Outstanding (Disbursed Only) (%)	100	100	100	100	100	100
Private Creditors (%)	54	61	64	64	63	57
Multilateral and Bilateral (%)	46	39	36	36	37	43
Total Commitments						
Average Interest Rate (%)	6.6	7.2	8.8	8.3	6.3	7.2
Average Maturity (Years)	11.8	11.4	11.6	7.8	11.2	10.5
Multilateral Commitments						
Average Interest Rate (%)		7.3	7.3	5.8	7.5	7.4
Average Maturity (Years)		20.0	21.5	17.4	20.5	17.9

SOURCE: World Debt Tables - Supplements External Public Debt of Developing Countries. February 12, 1979.

TABLE 3
PERU ELECTRIC SECTOR BORROWINGS

Project	External Financing Millions \$	Interest Rate %	Amoritization Years	Funding Source
Mantaro Hydroelectric Stage 1	52.6	6.6	12	Private Corporations
Mantaro Hydroelectric Stage 2	44.7	6.6	17.5	"
	17.3	8.2	12.0	"
	29.4	8.2	12.0	"
Chimbote - Trujillo Transmission and Central Station	9.0			Multilateral
Electrification for 22 Localities	6.9	7	10	Bilateral
Inquitco-Pucallpo Central Station	7.1	7	10	Bilateral
Canondel Pato Hydroelectric	9.7			Bilateral
LIMA CHIMBOLE Transmission	24.3	3.5	25	Bilateral
	5.1	3.5	25	
Lima Distribution	36.0	8.5	20	Multilateral

SOURCE: Ministerio de Energia Y Minas Plan Energetico A Largo Plazo 1978-1990 Y Perspectivas AC 2000, Diagnostico 1968-1977, July 1978.

3.0 MACROECONOMIC FACTORS AND ENERGY INVESTMENT

Projected total capital costs (investment cost plus estimated interest during construction) for the energy supply facilities in the Reference Case are estimated to be \$13,978 million (1978 dollars) over the period 1978-2000. Tables 1 and 4 give the details of these calculations for each of the major energy supply sectors by five-year intervals. The tables also present the share funded through domestic investment. The annual capital requirements are projected to grow from \$405 million in 1978 to \$871 million in the year 2000. The projected average of \$635 million per year is equivalent to roughly one-third of total 1978 Peruvian national investment, which indicates the major, if not dominant, role of the energy sector in overall national development. The potential impact of these investment

sums is heightened by the economic and financial problems that the Peruvian economy has recently experienced. These have included domestic investment requirements that exceed national savings, a worsening balance of trade, and large external borrowings (Table 5 provides data on some of these problems). Although the Peruvian economy grew at nearly 6 percent per year over the period 1970-75, substantial international and public deficits occurred that led to the economic crisis of 1977-1978. Energy investment requirements must be viewed in terms of reasonable future expectations for the Peruvian economy; recent experience suggests caution mixed with a degree of optimism. The Peruvian government has taken strong measures to right the economy, and these, together with the recent successful restructuring of the debt, provide an improved context for future energy needs. Projected energy investment requirements can then be analyzed in terms of the importance they place on the fulfillment of economic growth objectives and on the continuation of reforms in domestic savings incentives and investment planning and efficiency.

3.1 Energy Supply Investments and Aggregate Economic Growth Capacity

On the basis of the projected requirements for energy supply facilities in the Reference Case, energy investment is estimated to grow at a modest rate over the Assessment period - in the range 2.9-3.6 percent annually, depending on the subinterval under consideration (details are provided in Table 6). Compared to the long term Peruvian growth objectives that were used in the Assessment, this growth rate of energy supply investments appears appropriate, in that the 5 percent rate of GDP growth assumed for the period 1985-2000 represents a return to historical long-term growth trends after a slow recovery. (These and other data presented in Table 7 are drawn from discussions with the Peruvian Instituto Nacional de Planificaci3n about medium- and long-term economic plans in Peru.)

Using the GDP growth estimates, projected energy sector investments as a portion of Peruvian Gross Domestic Product remain roughly in keeping with past trends. Table 8 illustrates that the projected energy sector investment as a fraction of GDP is 2.9 percent in the year 2000, which is nearly identical to the historical 1968-1976 average of 2.8 percent (see Table 9). Projected electric sector capital requirements rise to a higher fraction of GDP than in the past, but this is counterbalanced by declines in petroleum sector investments. (This is consistent both with the Assessment findings about future petroleum availability and with the assumptions in the energy strategies that petroleum investment will support meeting domestic demand rather than additional development for oil exports.) Thus, given the importance of energy in attaining the country's economic growth objectives, the level of energy investment is in keeping with those goals.

3.2 Short- and Long-term Effects of Energy Supply Investments

3.2.1 Electric Utilities - The moderate rate of growth for capital investment in electric utilities (4.4 percent during the period 1978-2000 -- see Table 6) is lower than the projected growth in electricity demand that was assumed for the same period in the Assessment. This is a direct result of a large expansion in generating capacity that was near

TABLE 4

TOTAL CAPITAL COSTS FOR DESIGN, CONSTRUCTION AND STARTUP OF ENERGY FACILITIES
(MILLION DOLLARS, JAN. 1978)

REFERENCE CASE

	1980	1985	1990	1995	2000	1978-2000
Total Oil	246.	223.	192	220.	327.	5350.723
Total Gas	0.	0.	2.	6.	8.	64.058
Total Coal	0.	0.	7.	9.	15.	123.007
Conventional Hydro	146.	218.	146.	410.	421.	5512.779
Mini & Micro Hydro	4.	4.	4.	6.	6.	111.
Combustion Turbine	6.	17.	11.	6.	6.	197.
Diesel	26.	56.	38.	21.	4.	720.
Conventional Coal Fired	0.	0.	117.	0.	0.	425.
Total Generation	183.	315.	316.	450.	436.	7068.056
Transmission	53.	22.	24.	43.	47.	782.
Distribution	14.	23.	27.	33.	37.	590.
Total Utilities	249.	358.	368.	526.	520.	8440.636
Total Energy Industry	497.	581.	568.	759.	871.	13978.414

TABLE 5

MACROECONOMIC INDICES
1973 PRICES

Year	GDP	Export Volume	Import Volume	Gross Domestic Investment	Gross National Savings	Public Foreign Debt
1970	100	100	100	100	100	100
1975	134	78	158	202	84	326

SOURCES: Cuentas Nacionales del Peru 1960-1973 and Banco Central Reserva, 1974 and Worksheets; Ministry of Economy and Finance Public Debt.

TABLE 6
GROWTH RATES FOR TOTAL CAPITAL COSTS (%)

REFERENCE CASE

	SHORT RUN			MEDIUM RUN			LONG RUN		TOTAL		
	1979-82	1978-81	1980-83	1979-85	1979-86	1980-86	1985-2000	1986-2000	1978-2000	1979-2000	1980-2000
EXPLORATION, DEVELOPMENT, & PRODUCTION	-5.6	-0.7	-3.5	-3.9	-4.4	-4.1	1.2	1.8	-0.3	-0.3	0.0
TOTAL OIL	1.5	6.1	-11.3	.6	4.0	2.4	2.7	1.1	1.8	2.1	1.5
CONVENTIONAL HYDRO	-15.3	-12.9	3.8	4.6	3.8	6.4	4.5	4.9	4.3	4.5	5.3
TOTAL GENERATION	-1.7	-1.1	12.0	9.1	6.4	7.5	2.3	3.1	4.3	4.2	4.4
TOTAL UTILITIES	4.2	12.5	11.3	9.8	7.7	5.3	2.6	3.1	4.9	4.4	3.7
TOTAL ENERGY INDUSTRY	2.9	9.2	1.7	5.6	6.0	4.1	2.8	2.4	3.6	3.6	2.9

completion during the Assessment. However, over the short run (1978-1985), electric utility investment proceeds at a higher rate in precisely the years that are projected for the recovery of the Peruvian economy. As indicated in Table 7, economic growth of 1.8 percent for 1977-85, or 3.6 percent for 1980-85, contrasts to the 7.3 percent growth in electric utility capital requirements over the same period that is shown in Table 6. For the energy sector as a whole over this medium-term period, the high level of electric utility investment growth is only partially offset by declines in petroleum investments, so that the overall growth rate in energy investment requirements for the period 1978-85 remains near 6 percent per year. Although such levels of investment are appropriate not only to support a planned economic growth rate of 5 percent per year and a manufacturing growth rate of 6 percent per year but also to realize returns on such investments in post-1985 period, these investments may compete with other needed economic and social investments in the recovery years, especially in view of relatively restricted domestic savings rates and limited foreign borrowing capacity.

3.2.2 Petroleum Sector - The investment levels required to supply petroleum products for domestic consumption decline slightly over the period of the Assessment and, as discussed above, the decline of nearly 4 percent in the period 1978-85 lessens the overall energy sector investment burden. In the cases where demand is less than supply, projected growth of petroleum exploration development and production in the Reference Case has been constrained to meet estimated demand. It is possible that oil exports could be increased in these periods if additional oil exploration, development, and production investments were made. On the other hand, in the periods where the Assessment results indicate excess domestic demand for oil, the costs of the petroleum sector should include the cost of oil imports.

3.3 Energy Investment Requirements and Peru's Sectoral Growth Objectives

The planned levels of energy investment, particularly those in the electric sector, appear to be commensurate with the growth plans of the various sectors of the Peruvian economy. The Assessment was guided by the sectoral growth assumptions in projecting its demands for energy, and the energy investment costs reflect these assumptions, as well. Table 10 gives the average sectoral growth rates that were assumed for the Assessment. More detail on the sectoral objectives is provided in Section 3.2 of the Main Report and in Appendix D.

TABLE 7
GDP ESTIMATES ASSUMED FOR THE ASSESSMENT

1977	GROWTH RATES	GDP (MILLIONS 1979 \$) ESTIMATES
8	-2.	\$12,485**
9	-1.	12,235
80	0.	12,113
1	1.	12,234
2	3.4	12,662
3	4.5	13,233
4	4.5	13,828
5	4.5	14,451
6	5	15,173
7		15,931
8		
9		
90		18,443
1		
2		
3		
4		
5		23,538
6		
7		
8		
9		
2000		30,042

** U.S. Embassy "Key Economic Indicators" for 1978 estimates, with 1979-2000 projected from growth rate assumptions in Table 7 (above).

TABLE 8

CAPITAL REQUIREMENTS FOR THE PERUVIAN ECONOMY AND FOR TOTAL
ENERGY AND ELECTRICITY SECTORS AS A PERCENT OF GDP, 1968-1976

	GROSS DOMESTIC INVESTMENT/GROSS DOMESTIC PRODUCT* GDI/GDP	ENERGY SECTOR INVESTMENT/DO- MESTIC PRODUCT** ENERGY I/GDP	ELECTRICITY SECTOR INVESTMENT/GROSS DOMESTIC PRODUCT** ELECTRICITY I/GDP	ENERGY SECTOR INVESTMENT/TOTAL PUBLIC SECTOR INVESTMENT** ENERGY I/PUBLIC I
1968	13.9%	0.5%	0.4%	11.9%
1969	13.3	0.9	0.7	21.4
1970	12.9	1.6	1.3	35.1
1971	15.0	1.6	1.2	34.7
1972	14.2	1.6	1.2	32.8
1973	14.4	2.0	0.9	35.1
1974	17.3	2.4	0.6	29.7
1975	18.6	4.4	0.5	51.7
1976	16.0	4.5	0.6	56.5
1968-76 AVG	15.0	2.8	0.8	42.3

*Banco Central de Reserva del Peru Cuentas Nacionales del Peru, 1960-73.

**Ministerio de Energia Y Minas Plan Energetico a Largo Plazo 1978-1990 Y
Perspectivas al 2000, July 1978, corrected for difference between GNP
and GDP figures.

TABLE 9

ESTIMATES OF CAPITAL REQUIREMENTS FOR THE ENERGY SECTOR AND
ELECTRICITY SUBSECTOR AS A PERCENT OF GDP, 1980-2001[†]

REFERENCE CASE

	ENERGY INVESTMENT/ GDP	ELECTRICITY INVESTMENT/ GDP	ELECTRICITY INVESTMENT/ ENERGY INVESTMENT
1980	4.1	2.1	50.1
1985	4.0	2.5	61.6
1990	3.1	2.0	64.8
1995	3.2	2.2	69.3
2000	2.8	1.8	59.7

[†] Calculated from Table 2 and Table 12.

TABLE 10

AVERAGE SECTORAL GROWTH RATES ASSUMED FOR THE ASSESSMENT*

	1976-1985	1985-2000
BASIC PRODUCTIVE SECTORS	1.6%	5.0%
AGRICULTURE	1.1	3.5
FISHING	-2.7	2.5
MINING	6.3	4.0
MANUFACTURING	1.0	7.0
CONSTRUCTION	-0.7	6.0
SERVICE SECTORS	1.7	5.0
GDP	1.7	5.0

* 1978-1985 assumption based on discussions with INP and on their medium- and long-term plans. The 1985-2000 figures assume a return to long term growth trends. See Appendix D for additional discussions of macro-economic development plans.

Most important from the point of view of energy supply and demand is the planned emphasis on manufacturing and industrial development in the period 1980-2000. Manufacturing is projected to grow at approximately 4.7 percent annually from 1976-2000 and at 7 percent per year after 1985. This sector will be the principal user of expanded electricity production. The fact that overall energy investment continues at past levels indicates that such investments should not "bid" funds away from other sectors of the economy, provided that overall investment levels are maintained. However, since energy investments have in the past constituted over 40 percent of public sector investments (see Table 8), changes in growth of such investments could have a large effect on public investment in other sectors, particularly social services.

3.4 Peru's Capacity to Support and Utilize Energy Investments

3.4.1 Savings - The capital investment requirements of the Reference Case represent a continuation of past levels of investment. However, the question of the continued future availability of investment funds is of paramount importance. In past years, severe dislocations in the Peruvian economy have resulted from levels of domestic saving that were inadequate to support investment programs. Table 11 shows a comparison of domestic investment and national savings. The savings performance of Peru fell during the 1960's and 1970's from 22 percent of GDP in 1961 to less than 8 percent in 1975. The collapse of savings occurred in personal, business, and public savings. This placed the burden of investment financing on external sources and thus on Peru's future capacity for export earnings. Although expanding exports will support some of the planned investment burden in the future, it is neither desirable nor feasible to continue borrowing abroad at historical levels, and the mobilization of domestic savings thus appears to be a prerequisite of a successful investment program. For the energy

sector it may well be that foreign investment and financing will cover the energy facility import requirements, but at least one-third of the total energy sector capital costs (over \$4659 million) must still be generated in savings to cover the domestic share of investments over the period 1978-2000. The use of these savings for energy investments will depend on successfully "outbidding" other public and private sector investment demands for the funds. Since the public sector will make a significant portion of the energy investment, this may be possible. However, unless adequate overall levels of savings are available, investments in energy could come at the expense of other national objectives.

The Government of Peru has recently initiated measures that are aimed at increasing domestic saving. For example, the Government has moved in the banking sector to institute real rates of interest by year-end 1979, in order to attract private savings. The finances of state enterprises are being rationalized through elimination of unnecessary subsidies and the development of realistic pricing policies and more comprehensive taxation policies. Government saving will be increased by altering taxation procedures to keep tax revenues more in step with economic growth. This will also free government revenues somewhat from foreign trade movements, which have depended on changing prices and demands for primary export commodities. The importance of these reforms to Peruvian economic and energy development is further emphasized because such a large fraction of energy investment is expected to be in the public sector, where savings performance has been weakest.

TABLE 11

DOMESTIC INVESTMENT AND NATIONAL SAVINGS
COMPARISONS, AND EXTERNAL SAVINGS REQUIREMENTS, 1961-1975

	GROSS DOMESTIC INVESTMENT/ GDP GDI/GDP	GROSS NATIONAL SAVING/ GDP GNS/GDP	EXTERNAL SAVINGS/ GDP
1961	22.3	22.5	0.5
1962	22.8	22.0	1.4
1963	20.4	18.1	2.7
1964	18.7	19.5	-0.4
1965	18.6	16.0	3.3
1966	20.1	16.8	4.5
1967	19.8	15.1	5.6
1968	13.9	13.7	0.8
1969	13.3	14.2	-0.1
1970	12.9	16.6	-3.0
1971	15.0	15.1	0.4
1972	14.1	14.2	0.3
1973	14.3	12.8	1.8
1974	17.3	11.3	6.2
1975	10.6	7.6	11.2

SOURCE: Banco Central de Reserva del Peru, Cuentas Nacionales del Peru, 1950-1967, 1950-1965, 1960-73, and updates from Banco Central de Reserva del Peru.

3.4.2 Investment Efficiency - The great magnitude and broad scope of the required energy investments underline the importance of the careful consideration of investment criteria and economic incentives, both for energy sector investments and for the projects that will utilize the energy produced. For the energy sector, the predominant investments will be in public infrastructure components, such as electric power, from which returns must eventually be obtained in increased output of the directly productive industrial and commercial economic sectors. Without continued Peruvian measures to improve energy planning and to assure an energy pricing and tariff structure that reflects the relative scarcity of and alternative uses for energy, projects may be promoted that misallocate energy resources away from rational and internationally competitive uses. Such a misallocation would prevent the realization of maximum benefits for the investment expenditure. In addition, an energy investment should have a directly productive effect on any foreign exchange earnings that are needed to service an external debt that may have been contracted for its development. Finally, the return to the use of domestic funds will aid in securing savings and resources for future development in all sectors.

Although the scope of the Assessment did not include the analysis of rates of return for the projected energy projects, it is important that this step be taken as prospective projects are more fully considered. This analysis did include an alternative set of cost and debt calculations for both domestic and total investment that used a higher 12 percent interest rate. These results indicate the cost of money when the funds are valued in terms of returns on alternative projects. Those calculations can also serve to indicate a more appropriate cost of investment funds in later project evaluations than the 0 percent interest rate assumption that was used in the base analysis. Table 12 indicates the results of these alternate projections for domestic expenditures. Table 13 indicates the possible effects of changing the 12 percent interest rate. These include roughly a \$3,000 million difference in accumulated debt service that would need to be paid by the return from the investment projects (if the 12 percent interest rate were the prevailing market rate).

TABLE 12

CAPITAL COSTS FOR DOMESTIC INPUTS FOR DESIGN, CONSTRUCTION
AND STARTUP OF ENERGY FACILITIES (MILLIONS DOLLARS, JAN. 1978),
USING 12% INTEREST FOR ALL PROJECTS

REFERENCE CASE

	1978	1980	1985	1990	1995	2000	1978-2000
TOTAL OIL	79	79	64	59	89	131	1795
TOTAL GAS	0	0	0	1	3	4	27
TOTAL COAL	0	0	0	1	4	5	41
TOTAL HYDRO	65	68	86	77	169	164	2174
PETROLEUM FUELED	0	8	19	12	9	2	242
COAL FIRED	0	0	0	32	0	0	139
TOTAL GENERATION	66	77	112	120	178	166	2578
TRANSMISSION	0	21	8	11	18	21	341
DISTRIBUTION	7	12	18	22	26	30	471
TOTAL UTILITIES	73	109	138	154	223	217	3395
TOTAL ENERGY INDUSTRY	152	188	203	214	319	356	5252

TABLE 13

DEBT AND DEBT SERVICE FOR DOMESTICALLY PRODUCED INPUTS TO ENERGY SUPPLY
FACILITY INVESTMENTS: COMPARISONS WITH 0% and 12% INTEREST (MILLION 1978 DOLLARS)

REFERENCE CASE

	TOTAL DEBT 2000 0% INTEREST	TOTAL DEBT 2000 12% INTEREST	TOTAL DEBT SERVICE 1978-2000 0% INTEREST	TOTAL DEBT SERVICE 1978-2000 12% INTEREST
TOTAL OIL	596	775	587	1683
TOTAL GAS	13	17	3	15
TOTAL COAL	21	27	7	20
TOTAL HYDRO	1031	1218	181	1341
PETROLEUM FUELED	78	108	44	223
COAL FIRED	44	69	22	98
TOTAL GENERATION	1157	1502	252	1687
TRANSMISSION	143	183	39	258
DISTRIBUTION	218	282	45	308
TOTAL UTILITIES	1518	1966	336	2253
TOTAL ENERGY INDUSTRY	2147	2785	932	3971

3.4.3 Manpower, Materials, and Equipment Constraints to Energy

Investment - Peru's capacity to absorb the physical investments that are contemplated in the necessary energy expansion should be adequate over the period under consideration. Planned expansions in basic industries such as cement and steel will provide adequate supplies of these materials for the construction of the expanded energy infrastructure. Although a portion of other materials and technical manpower will have to be imported, the increased demand for such inputs caused by the energy investment program could provide incentives for the establishment of an adequate domestic capability over the longer term. Such a capability could eventually lower foreign exchange costs from imports, increase domestic employment, and improve the productive and competitive capacity of the Peruvian economy. Tables 14 and 15 give the annual costs and domestic shares for manpower materials, and equipment for the construction and for the operation and maintenance of the facilities, respectively.

3.5 Imports, External Financing and Debt Service

3.5.1 Import Requirements - Import requirements for investments in energy supply facilities are estimated to be \$9,318 million, or over two-thirds of the total investment requirements for the facilities. As Table 16 indicates, the imported share of total fixed capital investments for all sectors of the Peruvian economy has historically been much smaller: one-third of total capital has been imported, although the imported share rises to approximately one-half for machinery. While the facility cost estimates in this analysis reflect the ability of the Peruvian economy to provide significant amounts of local resources for energy facility development (see Annex 10 for the details), the energy facilities also require technologies, materials, and equipment which are currently produced economically only in other countries. Table 14 shows the estimates that were used: while 100 percent of non-manual, non-technical labor costs, and 72 percent of manual labor costs, are of domestic origin, only 32 percent of technical labor costs are Peruvian in origin, over 50 percent of materials and 90 percent of equipment must be imported from other countries. In large part the high level of imported labor costs reflects the very high cost differential (7:1) that currently exists between domestic (Peruvian) and expatriate labor. The large share of imported labor costs can be expected to decrease as Peruvian labor costs recover from their current depressed level.

SUMMARY OF CAPITAL REQUIREMENTS FOR MANPOWER, MATERIALS AND EQUIPMENT
(MILLION 1978 DOLLARS) FOR THE DESIGN, CONSTRUCTION
AND STARTUP OF ENERGY RELATED FACILITIES

REFERENCE CASE

	1977 (CALC'D)	2000	1978-2000 AVERAGE	1978-2000 TOTAL	PEAK (YEAR)	1978-2000 % DOMESTIC
NON-MANUAL TECHNICAL MANPOWER	7.	17.	12.	272.	17. (2000)	32.4
NON-MANUAL NON-TECHNICAL MANPOWER	0.	1.	0.	11.	1. (2000)	100.0
MANUAL MANPOWER	20.	47.	31.	717.	47. (2000)	72.4
MANPOWER TOTAL	27.	65.	43.	1000.	65. (2000)	61.8
MATERIALS TOTAL	106.	226.	149.	3421.	226. (2000)	46.9
EQUIPMENT TOTAL	162.	324.	243.	5591.	356. (1999)	10.6
CONSTRUCTOR COST TOTAL	333.	705.	506.	11629.	716. (1999)	27.6
TOTAL CAPITAL COSTS	423	871	608	13978	817	33.3

TABLE 15

ANNUAL COSTS (MILLION 1978 DOLLARS) FOR THE
OPERATION AND MAINTENANCE OF ENERGY-RELATED FACILITIES

REFERENCE CASE

	TOTAL 1978-2000	AVERAGE 1978-2000	1977 CALC'D	2000	PEAK (YEAR)	78-2000 % DOMESTIC
NON-MANUAL TECHNICAL MANPOWER	290	13	7	20	20 (2000)	88.6
NON-MANUAL NON-TECHNICAL MANPOWER	118	5	3	8	8 (2000)	100.0
MANUAL MANPOWER	894	39	20	62	62 (2000)	93.4
MANPOWER TOTAL	1302	57	30	90	90 (2000)	93.0
MATERIALS TOTAL	1169	51	29	83	83 (2000)	52.4
EQUIPMENT TOTAL	1520	66	34	104	104 (2000)	23.0
UTILITIES TOTAL	236	10	7	17	17 (2000)	100.0
SERVICE AND MISCELLANEOUS	776	34	17	51	51 (2000)	73.8
ANNUAL OPERATING COST (EX FUEL)	5002	217	117	345	345 (2000)	59.6

TABLE 16

LOCAL AND IMPORTED COMPONENTS OF PERU'S FIXED
CAPITAL FORMATION, 1968-1975
(Percentages)

	1968	1969	1970	1971	1972	1973	1974	Est. 1975
FIXED CAPITAL FORMATION	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
LOCAL	70.4	71.7	74.6	74.5	78.1	75.2	70.1	68.5
IMPORTED	29.6	28.3	25.4	25.5	21.9	24.8	29.9	31.5
MACHINERY	54.5	52.2	51.7	50.8	48.2	52.6	57.0	57.1
LOCAL	26.9	26.2	28.2	26.9	28.1	29.6	29.3	28.8
IMPORTED	27.6	26.0	23.5	23.9	20.1	23.0	27.7	28.3
CONSTRUCTION	45.5	47.8	48.3	49.2	51.8	47.4	43.0	42.9
LOCAL	43.5	45.4	46.4	47.5	50.0	45.5	40.9	39.7
IMPORTED	2.0	2.4	1.9	1.7	1.8	1.9	2.1	3.2

SOURCE: Banco Central de Reserva del Peru, Worksheet

3.5.2 External Debt, Debt Service, and Foreign Exchange Requirements- Foreign borrowing to finance energy supply facilities is estimated to be \$9,318 million (\$7,255 million if oil exploration development and production is not included and assumed to be provided by foreign direct investment) and to result in an outstanding external debt of \$3,498 million (\$2,909 million without oil) in the year 2000. Debt service on this borrowing would accumulate to \$6,498 million (\$4,644 million without oil) over the entire period, with annual debt service requirements reaching \$439 million (\$351 million without oil) in the year 2000. Table 17 displays these levels of debt and debt service. The analysis that leads to these results assumed as an upper bound that all energy facility imports, including those for oil exploration, development, and production, would be externally financed. (The alternative assumption in the "without oil" entries is that borrowings for petroleum exploration, development, and production would attract direct foreign investment or be easily repayable in foreign exchange in the form of exports. In any event, since this analysis did not examine the investment choices open to foreign investors, or payments to them, it was felt that the most straightforward representation of such outflows would be in the form of debt service.) These assumptions, the financing sources, the 8.5 percent interest rate, and the average 15 year amortization period, were presented and discussed in Section 2 of this Appendix. It should be noted that because there were no estimates available regarding energy debt service for borrowings prior to 1977, the debt and debt service are only for facility construction after 1977.

The estimates of external debt and debt service required to develop the energy supply facilities show a significant increase above historical levels, even under the alternative assumption that all imports for petroleum facilities are externally financed through direct foreign investment and, thus, do not appear in the debt estimates. Table 18 shows that total Peruvian external public debt ranged from \$1,048 million to \$3,000 million (or from 14 to 22 percent of GDP) in the 1972-75 period that immediately preceded the economic-financial crisis. As Table 19 shows, assessment estimates for Peruvian energy debt alone, i.e. excluding oil exploration, development; and production investments, reach 11.6 percent of projected GDP in the year 2000, while debt service estimates reach 1.5 percent of GDP in that same year.

For a better perspective the relative size of these debt estimates, Table 20 presents recent statistics for debt service on external borrowings in the electric power sector in Peru. These show that debt service as a percentage of GDP peaked in 1975 at 0.5 percent and generally ranged around 0.2 percent per year. In the Reference Case projection in this Assessment, electric utility debt service reached 0.9 percent of GDP, a level more than twice that in the peak historical year (see Table 19). It is important to note that most future investments in electric utilities will be in the public sector (in contrast to the significant private sector participation that characterized historical patterns), and that as a result these higher estimates of public sector electric utility debt may overstate the change in costs to the economy. Nonetheless, higher levels of debt and debt service in the electric utility sector are likely to increase pressures for more

TABLE 17

FINANCIAL STATISTICS FOR IMPORTED INPUTS FOR THE DESIGN, CONSTRUCTION
AND STARTUP OF ENERGY RELATED FACILITIES (MILLION 1978 DOLLARS)

REFERENCE CASE

	TOTAL CAPITAL COSTS		TOTAL DEBT TO DATE		TOTAL DEBT SERVICE	
	TOTAL	W/OUT OIL	TOTAL	W/OUT OIL	TOTAL	W/OUT OIL
1977	279	156	539	368	0	
1978	270	148	763	486	38	25
1979	283	162	976	604	64	38
1980	329	214	1214	763	86	48
1981	359	238	1453	926	120	73
1982	307	199	1615	1035	146	88
1983	349	241	1798	1172	172	106
1984	360	261	1964	1307	206	132
1985	402	393	2155	1473	215	135
1986	417	325	2336	1642	238	152
1987	373	280	2441	1738	283	192
1988	453	359	2610	1901	294	199
1989	430	338	2733	2025	310	211
1990	380	297	2780	2085	343	240
1991	330	248	2758	2079	368	263
1992	381	305	2777	2124	370	352
1993	407	325	2817	2179	387	283
1994	466	388	2913	2293	378	272
1995	479	403	3012	2408	379	280
1996	445	375	3061	2477	413	316
1997	479	407	3141	2572	407	314
1998	500	423	3233	2672	412	321
1999	562	471	3376	2807	431	342
2000	557	455	3498	2909	439	351
78-2000						
TOTAL	9319	7168	3498	2909	6498	4644
78-2000						
AVERAGE	405	312			283	201

NOTE: "Without oil" means that the figures exclude any debt or debt service which might have accrued for oil exploration, development, or production.

TABLE 18

EXTERNAL PUBLIC DEBT - PERU, 1972-1977

	1972	1973	1974	1975	1976	1977
TOTAL DEBT OUTSTANDING (DISBURSED ONLY) (%)	1048	1432	2213	2998	3689	4659
TOTAL DEBT SERVICE (MILLION U.S. \$)	182	398	431	436	454	652
DEBT/GDP (%)	14.0	15.8	19.4	21.7	26.9	37.9
DEBT SERVICE/GDP (%)	2.4	4.4	3.8	3.2	3.3	5.3
DEBT SERVICE/EXPORTS (%)	14.0	15.8	19.4	21.7	26.9	37.9

SOURCE: World Debt Tables - Supplements External Public Debt of Developing Countries, February 12, 1979.

TABLE 19

PROJECTED EXTERNAL DEBT AND DEBT SERVICE
FOR ENERGY SUPPLY FACILITIES
AS PERCENT OF GDP

	REFERENCE CASE	
	1995	2000
TOTAL ENERGY INDUSTRY DEBT/GDP*	12.8 (10.2)	11.6 (9.7)
ELECTRIC UTILITY DEBT/GDP	8.0	7.2
TOTAL ENERGY EXTERNAL DEBT SERVICE/GDP*	1.6 (1.2)	1.5 (1.2)
ELECTRIC UTILITY EXTERNAL DEBT SERVICE/GDP	0.9	0.9

* First figure assumes borrowing for oil exploration development and production. Figure in parenthesis assumes no borrowings for oil exploration development and production.

TABLE 20

ELECTRIC POWER SECTOR EXTERNAL DEBT SERVICE, 1968-1975

	1968	1969	1970	1971	1972	1973	1974	1975
DEBT SERVICE (THOUSAND U.S.\$)	6312	5361	4970	3597	8264	18766	52285	28300
DEBT SERVICE/GDP (%)	0.1	0.1	0.0	0.1	0.1	0.2	.5	0.2
ELECTRIC DEBT SERVICE/TOTAL DEBT SERVICE %	4.9	4.0	3.0	1.7	3.8	4.3	11.5	6.0

secure rates of return from electricity projects that are accompanied by sound industrial investments that will use the additional power generated.

External financing, debt service, and foreign exchange requirements nearly crippled the Peruvian economy over the last three years. Only recently has the situation begun to reverse itself as a result of vigorous fiscal, monetary, and financial measures coupled with debt restructuring. This lends increased significance to the magnitude of the projected energy sector external debt and debt service requirements, although the problem may not be as severe as the figures first suggest. The impact may be lessened by several factors that have already been mentioned:

- 1) It is Peru's stated objective to focus its foreign borrowing on productive sector investments, so that a substantial shift in public debt structure toward energy infrastructure could be expected.
- 2) Measures recently taken to strengthen the economy's domestic savings in both the public and private sector could reduce requirements for external borrowing. This will, perhaps, also permit domestic savings to cover some energy sector imports, thus lowering external financing requirements below the 66 percent found in the analysis. Steps to encourage direct foreign investment will also provide added latitude in financing. Further, these measures, and refinancing assistance from the IMF, should eliminate the reliance on short-term, high interest borrowing that has occurred in periods of high deficits, and made debt, and debt service, so intolerable.
- 3) The government's focus on increased export potential in manufacturing and non-traditional sectors will lessen the risks the country has incurred in the past by relying on the primary sectors, and their fluctuating foreign prices, for export earnings.

Despite these mitigating factors, the projected level of energy sector debt and debt service is very large. Their size also increases economic vulnerability during a downturn, and this could possibly affect the availability of financing. However, the debt and debt service requirements are within the economic capability of the country, especially when recent Peruvian economic-financial reforms and its development objectives are considered.

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