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Volume I: Regional Assessment

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ABSTRACT

This report presents an energy assessment of six Central American countries - Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama - to assist these countries in defining, planning, and meeting energy requirements implicit in their economic and social development goals and also to assist the U.S. Agency for International Development and other development organizations in defining energy programs in Central America.

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EXECUTIVE SUMMARY

1.0 PURPOSE

This report presents an energy assessment of six Central American countries - Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. The major objectives are to assist these countries in defining, planning, and meeting energy requirements implicit in their economic and social development goals and to assist the U.S. Agency for International Development and other development organizations in defining energy programs in Central America.

2.0 THE CENTRAL AMERICAN REGION

2.1 Background

The six countries of the isthmus of Central America are shown on the map in Figure E-1. The area, which covers 421,000 square kilometers, has a population of approximately 20.8 million growing at an average rate of 3.2 percent annually. Its dominant geographic formation is a chain of volcanic mountains running northwest to southeast from Mexico to Panama. A belt of tropical lowlands borders the Caribbean side, and on the Pacific side slopes are rich in volcanic soils with high agricultural yields.

Central America's economy depends upon a small range of agricultural products, and price fluctuations of these commodities affect export earnings. Well over half of total earnings come from three products: coffee, bananas, and cotton.

2.2 Energy Resources

Hydro Resources

The combination of high annual rainfall and steep terrain give Central America a large resource base for hydroelectric development. Although accurate data are not yet available, an order of magnitude estimate of potential regional generating capacity is over 30,000 MW. These range from over 10,000 MW in Guatemala to under 1,500 MW in El Salvador.

Geothermal

Each of the Central American countries possesses proven or potential geothermal resources. Geothermal development is the most advanced in El Salvador, where one-third of nonhydroelectric generating capacity is now geothermal (60 MW). Guatemala, Costa Rica,

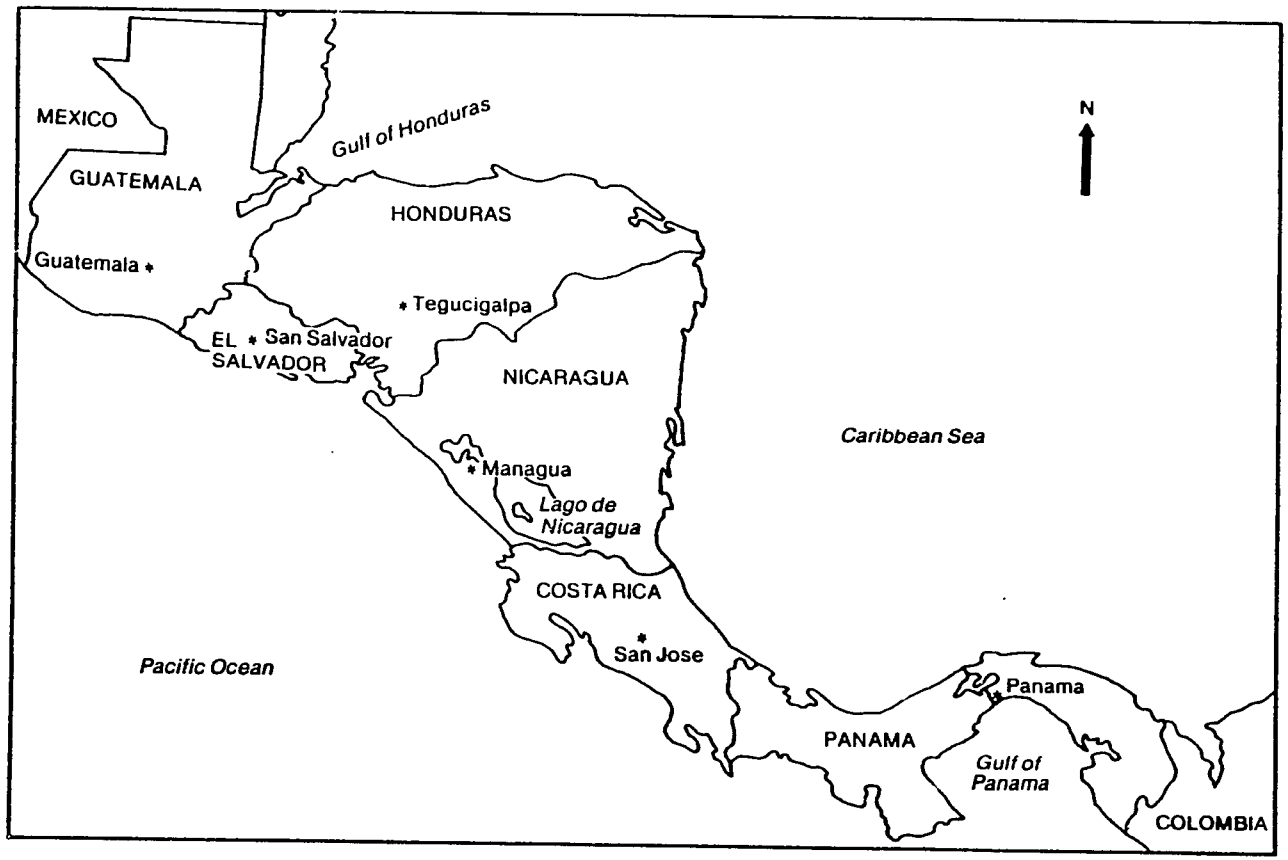

FIGURE E-1
CENTRAL AMERICA

and Nicaragua are exploring and developing geothermal sites for electric generation in the mid 1980s.

Petroleum

Central American nations have undertaken petroleum exploration only sporadically. Guatemala has proven oil reserves of over 10 million barrels, and is beginning to explore deeper strata which may eventually yield 100 million barrels. To date, Guatemala is the only nation in this region with commercially recoverable reserves.

Coal and Oil Shale

Significant coal and oil shale reserves have not been uncovered although small amounts of lignite appear throughout the region.

Solar

Direct solar energy for crop drying has been used for many years in Central America. Sunlight is intense in most areas, but reliable data on insolation in most cases are unavailable.

Wind

Although wind energy data are somewhat sparse, the velocity and uniformity of wind at specific high elevation and coastal sites in Central America appear promising for future energy use.

Biomass

About one-half of Central America is covered by forest, an area of over 25 million hectares. Over half of the coniferous forests are in Honduras, which supplies one-half of the timber cut in Central America.

Crops are another aspect of the biomass resource base. All countries in the region have large sugar industries which yield a residue, bagasse, which is already used in sugar processing. Approximately 300 thousand hectares of sugar cane were harvested in 1978. Large potential biomass resources also exist in the form of crop residues from coffee and bananas.

2.3 Current Energy Use in Central America

Table E-1 summarizes the energy use of Central America in 1977. Energy use is primarily petroleum-based, although noncommercial fuels, such as wood and charcoal, account for about one-third of

TABLE E-1

CENTRAL AMERICA

ENERGY RESOURCE CONSUMPTION, 1977

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Total
Total Resource Consumption (TJ)	99,909	73,662	52,082	59,136	69,638	88,966[2]	443,393
Allocation of Resource Consumption (percent)							
Hydro[1]	3.3	9.4	13.0	2.8	25.7	8.0	9.8
Geothermal[1]	-	7.8	-	-	-	-	1.3
Petroleum	51.0	44.5	46.3	65.0	44.0	76.5	55.3
Bagasse	10.7	8.3	5.5	12.0	9.4	4.8	8.5
Firewood and Other	35.0	29.9	35.2	20.2	20.8	10.7	25.1
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[1]Expressed in "equivalent of petroleum" (the amount of petroleum that would have been used to generate the same amount of electricity).

[2]Excludes exports.

Source: See country energy flow diagrams in Volume II of this report.

total regional consumption. Petroleum consumption in 1977 amounted to 40.0 million barrels. Total petroleum consumption, excluding Panama's, grew at a rate of 7 percent from 1968 to 1976, with diesel consumption growing at over 8 percent and bunker at about 7.5 percent. Gasoline consumption grew more slowly at 5.7 percent per year. More recent data (1977-1979) show diesel consumption growing faster due to fuel switching (gasoline vehicles to diesel vehicles) in response to price differentials.

The electrical sector in Central America operated 2,123 MW of installed capacity in 1977. The breakdown by energy type is 892 MW, hydro; 1,171 MW, thermal (steam, diesel and gas turbines); and 60 MW, geothermal. Significant additions of hydroelectricity capacity are scheduled to come on line between now and 1982 in Costa Rica, Guatemala, and El Salvador, which will make the region's hydro capacity at least 50 percent of the total. Between 1965 and 1977 the yearly growth rate of electric generation for the region was about 10.6 percent.

3.0 ENERGY STRATEGIES IN CENTRAL AMERICA

In this study, energy demand projections were developed to identify future Central American energy problems and to analyze alternative energy strategies to resolve these problems. Table E-2 presents a summary of projected energy resource use for the region in the year 2000. The Case I projection uses historical petroleum/GNP relationships. The Case II projection assumes much lower petroleum/GNP ratios. Petroleum demand is projected to rise by 3.6 (Case II) to 5.4 (Case I) percent annually to the year 2000. Noncommercial fuel requirements are projected to rise by 2.9 percent per year. Both of these demand characteristics present major energy problems in the region. Oil imports are already creating balance-of-payments burdens, and the local depletion of wood resources has created serious economic, ecological and social problems.

The strategies which could counter this future consist of imported oil substitution, energy conservation and rural energy development. These are described in Figure E-2.

3.1 Imported Oil Substitution

The strategy for substitution of future oil needs, viewed here as an imported oil requirement, consists of the following:

- discovery and development of indigenous oil reserves
- substitution of oil in electric power generation

TABLE E-2

CENTRAL AMERICA

PROJECTED ENERGY RESOURCE USE, YEAR 2000

		Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Total
CASE I	Total Resource Consumption (TJ)	406,318	244,800	152,616	193,046	269,804	320,441	1,587,025
	Allocation of Resource Consumption (percent)							
	Hydro[1]	23	17	28	16	41	28	26
	Geothermal[1]	5	12	-	11	4	-	5
	Petroleum							
	Direct	40	35	43	39	42	58	43
	Electricity	11	12	-	13	-	7	8
	Firewood and Other	21	24	29	21	13	7	18
		100	100	100	100	100	100	100
CASE II	Total Resource Consumption (TJ)	343,171	217,399	131,336	168,233	229,046	255,137	1,344,322
	Allocation of Resource Consumption (percent)							
	Hydro[1]	28	19	33	19	48	35	31
	Geothermal[1]	6	14	-	13	4	-	6
	Petroleum							
	Direct	28	27	33	30	33	47	33
	Electricity	13	13	-	15	-	9	9
	Firewood	25	27	34	23	15	9	21
		100	100	100	100	100	100	100

[1] Expressed in "Fossil Fuel Equivalent" assuming a conversion efficiency of 0.25.

Source: See Energy Projections in Volume II of this report.

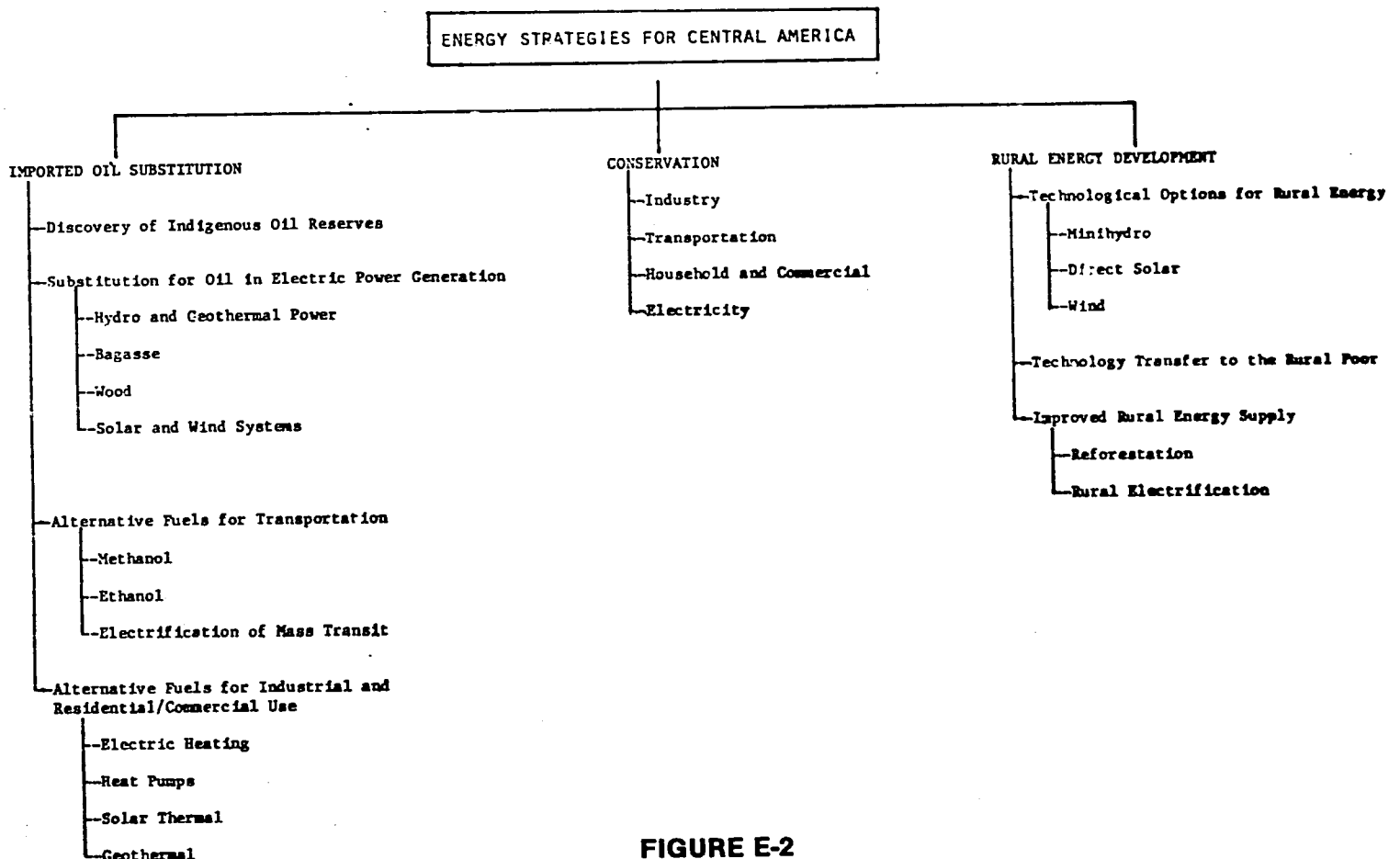

FIGURE E-2
ENERGY STRATEGIES FOR CENTRAL AMERICA

- substitution of alternative liquid fuels for transportation
- substitution of oil in industrial, residential and commercial use

Discovery of Indigenous Oil Reserves

Except for recent discoveries in Guatemala, Central America has not yet located economically extractable oil resources. These six nations need to consider increased geological studies and exploratory drilling. Oil exploration is a high-cost and high-risk enterprise, yet the benefits are so attractive that petroleum exploration should be encouraged.

We suggest a structured and intensive approach to oil exploration: careful planning, timetables for exploration, government analyses and interpretation of private company findings, well structured laws for granting concessions, and regulation of drilling and production.

Substitution for Oil in Electric Power Generation

For the Central American region as a whole, it is expected that there will be substantial untapped hydroelectric and geothermal potential in the year 2000, far exceeding planned installed capacity. This can provide large-scale substitution for oil in generation of electricity. On a smaller scale, there is bagasse, presently inefficiently utilized. There appears to be a potential for generating surplus electricity in sugar mills which then would be fed to the grid. In addition, isolated communities in certain regions may be able to substitute wood for diesel systems now in use.

In the longer range, solar thermal and wind electric power systems are important options to pursue, especially in nations where hydro and geothermal resources are inadequate for future electricity demands.

Alternative Fuels for Transportation

Probably half of total petroleum use by year 2000 will be for transportation. Production of methanol (from trees) and ethanol (from sugar cane or other crops) should be investigated in depth.

Methanol from woody biomass has significant oil substitution potential in Central America. Approximately 30 percent of the Case I year 2000 petroleum demand for Central America could be substituted by methanol if 10 percent of annual renewable growth of the forests and woodlands in the region are utilized.

The strategy for using methanol to displace petroleum in the transportation (or any other) sector must take into account the competition for fuelwood among other users, and the potential environmental consequences.

Ethanol from sugar cane is the second major liquid fuel substitute for petroleum in the transportation sector. A regional production of 309 million liters of ethanol (obtained from an equivalent of 25 percent of present sugar cane production) amounts to about 1 percent of Case I projected petroleum demand.

Alternative Fuels for Industrial and Residential/Commercial Use

In cases where electricity can be produced from indigenous resources such as hydro and geothermal power, oil use can be reduced by converting end-use heating systems from oil to electricity. Oil-fired hot water systems and oil-fired steam process heat systems can be replaced with electric heating systems. Waste recovery systems, solar thermal systems, and direct applications of geothermal resources are other alternatives to petroleum for low temperature heat requirements.

3.2 Energy Conservation

The potential for industrial energy conservation is a function of the types of industries, the types of equipment used in these industries, and the ways the equipment is managed. In the U.S., targets for conservation for various industries are in the range of 13 to 25 percent. Experience suggests that the first 10 percent of savings are typically attributable to better energy management, and the balance to programs involving minor capital investment at existing plants. Conservation programs to improve existing plants, and to ensure that new plants are properly installed and operated can contribute effectively. It is our judgment that a reduction of 10 to 20 percent in energy demand in industry is possible (beyond the reduced demand due to price effects) if vigorous conservation programs are instituted.

There is wide variation in the fuel efficiency of automobiles currently available in new and used car markets. A number of policy options, such as taxation, import policies, and tune-up programs could accelerate the move toward a more efficient automotive fleet. Such initiatives could be particularly important in freight transport, which accounts for at least 50 percent of transportation energy use in the region.

A second strategy for the transportation sector is to shift toward more efficient transport modes, particularly from private vehicles to mass transit and from truck to rail. While this strategy may take longer to accomplish, it has an even greater potential impact, since the energy efficiency between modes can vary by factors of 2 to 4.

A reduction in transportation energy consumption of 15 to 25 percent below projected values by 2000 may be feasible with vigorous government action.*

3.3 Rural Energy Development

Rural energy use is concentrated in "noncommercial" fuels, such as fuelwood, charcoal, and bagasse. Inasmuch as rural energy consumption is large throughout Central America, price and availability of supply have a great impact on the rural economy. Rising fuelwood prices have had a proportionately larger impact on the income of the poor. Thus, improvements in supply and efficiency of noncommercial fuels have greater significance for the poor than for other income sectors of the population.

Solutions to rural sector energy problems can take many forms. Sociopolitical reforms, such as changes in rural land tenure, can boost income of the rural poor. Changes in cultural values can influence the type of technology utilized and the speed with which it is adapted. Financial/fiscal incentives and disincentives can likewise influence production and income. However, the consideration of technological solutions and their implementation are most relevant to the energy question.

Mini hydro has significant potential for displacing expensive existing or potential diesel generators in isolated rural areas, providing longer hours of service and thus opening up new opportunities for rural inhabitants. Direct solar probably has the greatest rural applicability for the drying of fuelwood and crops such as plantains, coffee beans, and maize. Wind generation of electricity, water pumping, and milling grain is also a potential energy source, particularly for islands and coastal areas.

Decreases in noncommercial energy use are possible through increased efficiency of energy use in the home and in industry through more efficient stoves for cooking and more efficient rural industrial

*Based on targets set by the U.S. Industrial Efficiency Improvement Program administered by the U.S. Department of Energy.

technologies (for brick and lime kilns, bakeries, sugar refineries, etc.).

The mechanisms for the transfer of new energy ideas and technologies to the rural poor require careful consideration. To be effective, technology transfer must be accompanied by education and participation of the intended beneficiaries. Two suggested mechanisms are the use of extension services (agricultural organizations, universities, and/or private institutions) and the development of rural energy experimental stations.

Reforestation efforts in Central America must be achieved to guarantee a long term supply of fuel wood for the rural poor. Institutions working in reforestation need to obtain the participation and support of the rural population.

Finally, rural electrification programs, recently deemphasized as a result of poor economic returns, need to be continued both as a method for reducing fuel wood use and as a means to encourage rural development.

4.0 RECOMMENDATIONS TO USAID FOR CENTRAL AMERICA ENERGY PROGRAMS

The following recommendations apply to the entire region of Central America.

1. USAID should support country governments in the development of energy policy making institutions and the energy analysis capabilities requisite in these offices.

2. USAID should support energy conservation program development in Central America. Two activities can be undertaken promptly:

   a. Energy consumption and conservation analyses.

   b. Training and institutional support.

3. USAID should support the development of biomass-based liquid fuels in Central America. Four specific programs are recommended:

   a. Sugarcane to ethanol fuel assessment.

   b. Sugarcane to ethanol demonstration project.

   c. Wood to methanol fuel assessment.

   d. Wood to methanol demonstration project.

4. USAID should support rural energy programs in Central America by:

   a. Establishing energy demonstration and extension centers.

   b. Strengthening national forestry institutes and national reforestation programs.

   c. Supporting of community energy projects.

5. USAID should support renewable energy resource assessments in Central America.

6. USAID should support innovative energy research in Central America.

7. USAID should encourage the dissemination of energy development information in Central America.

   a. USAID should require that major USAID energy projects include mechanisms for regional dissemination of results.

   b. USAID should support regional energy conferences on specific energy development needs.

   c. USAID should support regional energy training programs.

   d. USAID should investigate the potential for a Central American energy information dissemination system.

8. USAID should continue to support regional energy institutions such as SIECA/COMENER, ICAITI and CATIE.

1.0 INTRODUCTION

1.1 Purpose

This report presents an energy assessment of six Central American countries: Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. This work was undertaken to satisfy the following objectives:

- to assist the Central American countries in defining, planning, and meeting energy requirements implicit in their goals for economic and social development
- to assist USAID and other development organizations in defining energy programs in Central America

1.2 Approach

This project began with a systematic data search for Central American energy and energy-related information available in the United States. Primary sources were USAID, the World Bank and Inter-American Development Bank, the International Monetary Fund, various organs of the United Nations, the Organization of American States, the Central American embassies, and computerized energy data-retrieval systems.

The second phase of this project took place in Central America. Two-person teams visited five Central American countries for approximately two weeks. With the assistance of USAID missions in each country, teams met with country energy officials. Data obtained during these visits were invaluable. At the end of this period, MITRE compiled and published a working paper containing an anotated bibliography of all the energy data collected from the United States and from Central America.*

*M. Hallford and W. Park, Central America Energy-Related Data Sources, WP-80W00024. McLean, Virginia: The MITRE Corporation, 1980.

The last phase of this study was the analysis phase. MITRE/E/DI staff prepared data on energy resources, use, and projections for each of the Central American countries using a common format and methodology. Descriptions of energy R&D activities and energy-related institutions were also compiled. The team then outlined and assessed strategies for the resolution of Central American energy issues. Finally, MITRE and E/DI defined regional and country recommendations to assist USAID and other development organizations in the definition of future energy programs in this area.

1.3 Document Overview

This report is published in two volumes. Volume I contains a regional energy assessment and regional recommendations to USAID. Volume II parallels Volume I on a country-by-country basis for the six countries.

Section 2 of Volume I begins with a summary of Central American energy issues. This discussion defines the problem and introduces the approach. Section 2.2 presents a geographic, economic, and social picture of the region stressing factors that relate to energy. This section also contains a summary of Central America energy-related institutions and a discussion of how these institutions affect energy policy and development.

Against this background, Sections 2.3 to 2.5 present current and future energy patterns within the region. Section 2.3 assesses available energy resources; Section 2.4 summarizes current energy use; Section 2.5 presents projections of year-2000 energy consumption based on economic projections for each nation. For a better perspective of potential energy-consumption patterns, two scenarios are given, Case I and Case II. Case I projects year-2000 energy

demand based on traditional economic-energy-development relationships. Case II is a more conservative energy projection which assumes a significant reduction in the need for energy in development.

Section 2.6 describes strategies for resolving or mitigating the energy problems in the region. Where possible, the report presents estimates of the potential effects of each of the strategies based on the availability of indigenous energy resources. These impacts are then related to Case I energy projections.

Section 3.0 provides recommendations to USAID for future energy programs in Central America given that the Central American countries will need to pursue some or all of the energy strategies discussed. They are also based on perceived needs of the country governments and support provided from other development institutions.

The energy assessments in Volume II are organized in the same manner as Volume I. USAID recommendations in Volume II include both refinements to the regional recommendations as applied directly to specific countries, and country-specific recommendations.

A list of conversion factors used in this report, a list of the Central American energy contacts, and a bibliography appear at the end of this volume.

2.0 CENTRAL AMERICA REGIONAL ENERGY ASSESSMENT

2.1 Central America Energy Issues

Two essential problems characterize the energy situation in Central America. The first is the supply and cost of imported petroleum; the second is the supply of fuels to rural areas. Although we will discuss these problems separately, they are closely related. Higher prices for petroleum-based fuels are making them more unaffordable just when the shortage of non-commercial fuels is making petroleum use desirable.

2.1.1 The Oil Problem

Higher oil prices have affected the countries in Central America in two ways. The first, a macroeconomic effect, has to do with the impact that the national expenditures for oil imports have on the balance of payments. The second, a microeconomic effect, has to do with the impact on households, industries, and commercial establishments.

Without a doubt, the macroeconomic effect is a very serious one for all countries of the region. Table 2-1 gives an indication of the impact of oil import costs on national economics. It shows that, even with 1976 oil prices, oil imports consumed 10 to 15 percent of total export earnings. Regionally, higher oil import costs accounted for most of the increase in the trade-balance deficit which soared from $113 million in 1974 to $1,000 million in 1978. The price increases of 1979 can be expected to almost double those costs, and, if policies are not instituted to ameliorate the problem, deficits will continue to increase over the next decades.

This analysis of the oil issue suggests that strategies to confront the oil problem of these countries should pay particular

TABLE 2-1

CENTRAL AMERICA

FRACTION OF EXPORT EARNINGS DEVOTED TO OIL IMPORTS

(percent)

Country	1972	1974	1976
Costa Rica	5.9	13.7	14.0
El Salvador	4.1	8.3	10.0
Guatemala	6.8	15.1	15.0
Honduras	9.6	11.8	12.0
Nicaragua	6.4	12.7	-
Panama[1]	60.4	148.8	-

[1]Data excludes the Canal Zone; note that a large fraction of the yearly imports into Panama were for refining and foreign resale.

Source: World Bank Working Paper No. 346 and World Bank Development Report 1979.

attention to foreign exchange requirements. For example, resources or technologies which substitute for future oil demand at equivalent prices may be advantageous on the supply side if they have larger indigenous components than their oil-based competitors.

The second effect has direct social and political implications for each country of the region. Adverse effects are strongest for individual households and small commercial activities where fuel price increases cannot be easily absorbed or passed through. Particularly for poor families in both rural and urban areas, the direct costs of energy now represent significant portions of disposable income.

Less affected are some industrial and large commercial sectors. This is due to the fact that, in general, even with higher oil prices, energy represents a small fraction of total costs. Despite the significant oil price increases since 1976 and those likely in the future, the fraction of industrial energy costs to total costs should remain manageable. Moreover, industry has the opportunity to continually reduce energy consumption per unit of output through conservation.

Although the macroeconomic issues may initially be perceived as more remote from social concerns than microeconomic problems, progress in all of these countries ultimately depends on continued, balanced economic growth. Reduced growth rates affect employment, distribution of income, productivity, and social services. Solving macroeconomic energy problems is necessary if long-term social and economic aspirations are to be met.

2.1.2 Energy for Rural Areas

Traditionally, one element of the growth of oil consumption in Central America, as elsewhere in the developing world, has been the substitution of petroleum products for traditional fuels, particularly wood. With rising prices of kerosene and other fuels, this substitution has become more costly and less likely. At the same time, wood and the other traditional fuels of rural areas have become more scarce and more expensive.

According to ECLA estimates, the amount of fuelwood and charcoal used in Central American countries in 1975 was roughly equivalent in energy content to 16.4 million barrels of oil. Wood is used for cooking in approximately 80 percent of the households of the region.

Although the controversy over the exact causes continues, the price and availability of fuelwood aggravate the situation at least regionally.* Prices have risen anywhere from three to five times during the last ten years. Surveys in Guatemala, Honduras, and Costa Rica have indicated that in many locations the average daily cost of fuelwood ranges from 20 to 50 percent of the average daily wage.** The highest costs and most rapid price increases have occured in Guatemala, despite its large forest resources.

Many small-scale industries, key elements in successful rural development, also depend on wood. Lime kilns, bakeries, the tobacco industry, coffee processing plants, tile and brick factories are examples of industries which use wood as their principal energy source.

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*Regional Offices for Central American Programs (ROCAP) "Fuelwood and Alternative Energy Sources," August 16, 1979.

**Alfredo Mendez Dominguez, Fuelwood Use and Attitudes in Guatemala, Salvador, Honduras and Costa Rica, Report to ROCAP, August 1979.

The increased pressure on diminishing wood resources not only is imposing more severe economic and physical burdens on rural families and industries, but also is starting to create environmental problems. Although deforestation-induced erosion is generally in an early stage in Central America, the examples of northern India, Nepal and the Sahel should serve as grave warnings of the consequences of inattention to deforestation.

For many reasons, the dimensions of this rural energy problem are less well defined and the pressures for resolving the problem are less compelling to policy makers than for the petroleum problem. For one, although the general parameters are known, specific and reliable quantitative data are scarce. For another, organizing a response is more difficult, given the organizational settings to resolve the problem. Furthermore, infrastructure projects, such as hydroelectric plants, are much more concrete and manageable efforts. The appeal to strengthen the "modern," industrialized, and urban sectors of the economy also tends to draw attention away from confronting rural energy problems. Add the relative political advantages of satisfying urban and commercial/industrial constituencies and it is easy to see why accelerating efforts meet rural energy needs becomes a secondary priority.

2.2 Geographic, Social, and Economic Aspects of Central America Energy Development

2.2.1 Geography, Demography, Economy

Geography

Figure 2-1 shows the six countries of the isthmus of Central America. This area between Mexico and Colombia covers 421,000 square kilometers. Its dominant geographic formation is a chain of volcanic mountains, the Cordillera Central running northwest to southeast from

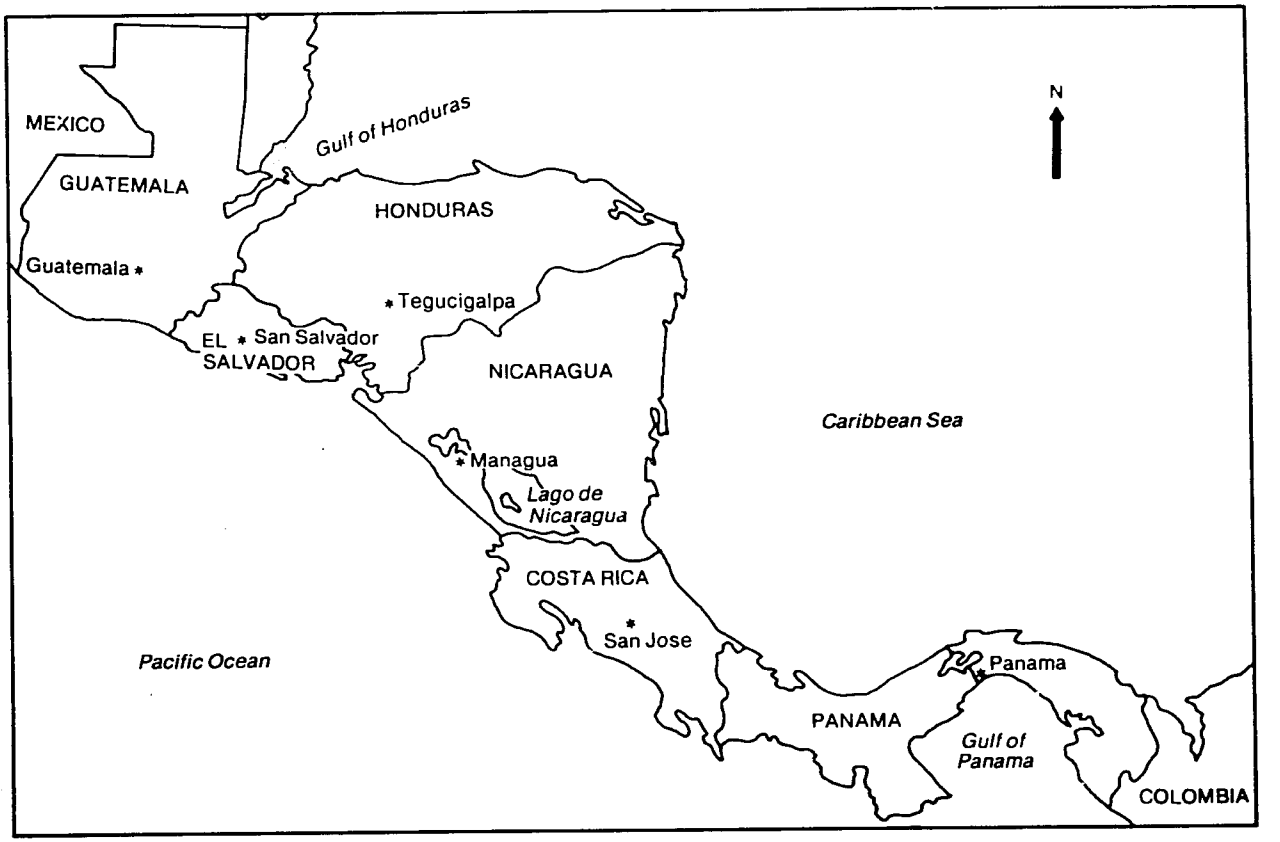

FIGURE 2-1
CENTRAL AMERICA

Mexico through Panama. A broad belt of tropical lowlands, well watered by the prevailing trade winds, borders this mountain chain on the Caribbean side. Since the mountains trap precipitation on this northern (Caribbean) side, rainfall along the Pacific lowlands tends to be lighter and more seasonal.

The Cordillera Central provides several opportunities for regional energy development. Abundant rainfall, complemented with substantial variations in altitude, provides the potential for extensive hydroelectric development. Also, extensive volcanic regions along the Cordillera have proven to contain significant geothermal energy resources.

Rich volcanic soils along the Pacific plains and slopes, together with moderate rainfall, provide the conditions for high agricultural yields. The less fertile Caribbean regions are dense with tropical rainforests. Once heavily forested with pines and hardwoods, extensive cutting is rapidly depleting the forest cover of these mountain and highland areas.

The regional ground transportation network is centered around the Pan American Highway, an all-weather road which follows the highlands and Pacific coastal plains from Mexico to the Darien peninsula in Panama. Railroads have historically developed as means to transport agricultural products to nearby port facilities and hence do not offer a viable means of inter-regional communication. River systems, while abundant, do not serve as navigable waterways for commerce.

Demography

The population of Central America totals approximately 20.8 million and is growing at an average rate of 3.2 percent annually

(see Table 2-2).* High birth rates are recent phenomena which have weighted the age profile toward younger age groups. This fact imposes difficult burdens on economies in the region which must provide social services and basic necessities to a population that contains a large non-productive component.

In spite of the high birth rates, all Central American countries, with the exception of El Salvador, have moderate to low population densities. In El Salvador, high population density and uneven land distribution, have contributed to emigration to neighboring countries.

Within each country, population is unevenly distributed. Typically, each nation has one or two large urban areas where government, industry, and commerce are concentrated. Nevertheless, more than 67 percent of the population lives in the countryside.

Economy

Central America's economic dependence upon a small range of agricultural products is striking. Well over half of total export earnings comes from three products: coffee, bananas, and cotton. This makes the region highly vulnerable to price fluctuations in the international market for these commodities.

The agricultural and service sectors are generally the largest in terms of contribution to GDP (see Table 2-3). The industrial sector contributes less than 25 percent to regional GDP; in Honduras and El Salvador, it contributes less than 15 percent.

Attempts at regional economic cooperation have been hindered by regional political disputes, often unrelated to economic issues.

*Source: Inter-American Development Bank, 1978.

TABLE 2-2

CENTRAL AMERICA

BASIC STATISTICS, 1978

Country	Total Population (thousands)	Annual Average Rate of Population Growth, 1970-1978 (%)	Inhabitants/ Square Kilometer	Urban Population (%)	GDP (in millions of 1976 U.S. $)	Per Capita GDP (in 1976 U.S. $)
Guatemala	6,622	3.1	59	31.0	5,831	880.5
El Salvador	4,397	3.2	202	40.1	2,703	614.8
Honduras	3,439	3.6	28	34.4	1,551	450.9
Nicaragua	2,393	3.1	18	55.5	1,864	778.9
Costa Rica	2,154	2.9	41	44.4	2,368	1,099.1
Panama	1,825	3.1	23	52.4	2,289	1,254.1
Regional Total/ Average	20,830	3.2		39.5	16,606	797.2

Source: U.N. Statistical Yearbook, 1978, and Inter-American Development Bank.

TABLE 2-3

CENTRAL AMERICA

CONTRIBUTION OF THE AGRICULTURAL SECTOR
TO GDP, 1970-74 and 1978

(percent)

	1970-74	1978
Guatemala	27.8	25.9
El Salvador	25.2	21.9
Honduras	34.7	31.2
Nicaragua	23.1	26.4
Costa Rica	22.8	19.2
Panama	16.6	15.4

Source: Inter-American Development Bank.

The Central American Common Market (CACM) was conceived as a large, protected market for regional manufacturers. The CACM was to abolish tariffs between members and erect a common external tariff barrier. Only limited progress toward regional economic integration has occurred. Instead, many Central American countries have entered into more effective bilateral agreements.

2.2.2 Energy-Related Institutions

Governmental Institutions

The major energy-related institutions in Central America are the national utility companies. In general, these are autonomous organizations authorized to plan, construct, and operate electric generation facilities. Projects are financed by national governments, the World Bank, the Inter-American Development Bank, the Banco Centroamericano de Integracion Economica, and the utilities themselves. Economists, engineers, geologists, chemists, and meteorologists are represented on the utilities' professional staffs, and the technical and administrative performances are excellent. Within the utilities, nonconventional energy resources for electric generation have caused some interest, but in terms of national energy policies, the utilities maintain specific immediate objectives.

Other agencies within each government that have energy-related responsibilities may include the Ministries of Planning, Agriculture, Commerce, Economics, Natural Resources, and Transportation. Whatever influence the agencies have on the development of national energy policies depends on factors like the agencies' interpretations of their roles, their relationships to the governments in power, and the governmental perceptions of the technical abilities of their staffs. Another important consideration is that energy issues, as priorities, compete with a host of other priorities, including health and education.

Ministries of Natural Resources, Ministries of Commerce or agencies within Ministries of Economy generally manage hydrocarbon resources. Many countries have passed legislation to regulate the operations of foreign oil companies.

Forest and agriculture resources are usually managed by Ministries of Natural Resources and Agriculture. Some of their programs involve considerable research, development, and outreach activities in energy-related areas.

Some countries have formed National Energy Commissions to facilitate interagency cooperation. Such commissions generally have few staff members, but nevertheless must recommend national energy policies. As a result, they usually suggest broad national energy goals and objectives, without analyses, strategies, and coordination mechanisms to achieve specific objectives.

The responsibilities of national energy agencies in Central America are dispersed, and coordination, cooperation, and information exchange are limited. Some agencies, though structured and staffed to provide a variety of services, do not have the power or resources to plan, develop, and implement programs.

Nongovernmental Institutions

The principal nongovernmental institutions which carry out energy-related research, development, and outreach programs in Central America are universities and private volunteer organizations.

The universities reflect popular pressure for education. They also embody the country's national pride, and its desire for modernization. Universities are generally oriented toward teaching rather than research. However, in some cases, special research funds are

sought and are established to provide financial support for energy-related endeavors. In general, these programs are not large. One of the largest is found at the Engineering Research Center at the University of San Carlos in Guatemala.

Other nongovernmental institutions are volunteer organizations promoting "appropriate" technologies at the grass roots. In general, the technologies which these institutions offer tend to be labor intensive, inexpensive, minimally complex, and small scale. Although their financial support is usually quite modest, private organizations have often succeeded because of the quality of their leaders and their use of indigenous personnel as change agents.

Regional Energy Institutions

A third type of energy-related institution in Central America is the regional cooperative organization, of which the Central American Common Market (CACM) is the best example. Established in 1960 to provide a unified market for goods and services, technical cooperation and coordinated resource management in Central America, the CACM has encountered political and administrative difficulties. Nevertheless, the CACM and its policy-coordinating arm, the Secretariat for the Economic Integration of Central America (SIECA), represent important vehicles for technical and economic assistance in the region.

Recently the CACM formed an energy policy body, COMENER, consisting of the subsecretaries of the Economic Ministries of CACM member states. In the interest of greater energy self-sufficiency, COMENER is designed to:

- encourage the use of renewable energy resources (including biomass, geothermal, and hydro)
- assist with the transfer of energy-related technologies

- encourage the rational use of petroleum in the transportation sector
- discuss financial arrangements for the purchase of petroleum from Venezuela
- participate in the United Nations Development Program in Energy by serving as a conduit for information exchange and dialogue

Coordination between this organization and member governments has just begun. However, COMENER has limited personnel and finances to coordinate these agencies and form policy. SIECA now exercises these functions.*

The Instituto Centroamericano de Investigacion y Tecnologia Industrial (ICAITI) and the Centro Agronomo Tropical de Investigacion y Ensenanza (CATIE) exemplify regional, private, nonprofit institutions in Central America. Both organizations are involved in energy-related projects.

ICAITI's energy projects have included:**

- development of an efficient process to extract and ferment sucrose from sugarcane
- development of solar grain-dryers
- production of biogas from coffee and agricultural waste
- implementation of a gasohol (i.e., ethanol/gasoline mixtures) research program
- standardization of solar data collection
- development of small-scale hydroelectric potential

*Based on information provided by SIECA.
**Based on information provided by ICAITI.

CATIE has made progress in training, research, and development projects in agriculture, forestry, and animal husbandry, wildlife conservation, watershed management, small farm silviculture, and small farm agro-forestry. In addition, both CATIE and ICAITI are cooperating with the (USAID) Regional Office of Central American Programs (ROCAP) in a project to reduce fuelwood demand through more efficient fuelwood conversion and through fuel substitution. The fuelwood project will provide for:

- production of fast growing trees and plants
- testing of fuel-efficient stoves for home use, kilns and charcoal makers, coffee and other agricultural dryers, and biogas and pyrolytic devices
- collaboration with national and international organizations to exchange information on fuelwood*

The United Nations

Another important development institution in Central American is the United Nations Development Program (UNDP). Since 1978, the UNDP has funded and technically supported the development of indigenous energy resources throughout the developing world. In the Central American context, six elements comprise the UNDP energy program:**

- development of basic data for energy analyses (planning, balances, training, and rational use)
- evaluation of petroleum information and laboratory experiments
- development of geothermal resources
- studies of electrical interconnections
- a prefeasibility study for an alcohol distillery plant
- development of three small-scale hydroelectric plants

*Based on information provided by ROCAP.
**Based on information provided by UNDP in Guatemala.

2.3 Central America Energy Resources

Hydro Resources

High annual rainfall and steep terrain give the region a large resource base for hydroelectric development. Although accurate regional data are not yet available, an order-of-magnitude estimate of potential regional generating capacity is over 30,000 MW. Table 2-4 presents national estimates lending to this total. These estimates range from over 10,000 MW in Guatemala to under 1,500 MW in El Salvador. According to long-term plans, all the countries, except El Salvador, foresee handling much of their future growth in electricity demand through hydro.*

The role of electricity in reducing foreign oil imports is particularly interesting. The time and money required to build large-scale hydroelectric plants assure opportunity for further assessment, planning, and evaluation within this context.

Small- and medium-scale hydroelectric systems, capable of generating 5 KW to 1 MW, have aroused interested throughout the region. Although small- and medium-scale units are under consideration for electric generation purposes in rural areas, it is recognized that they can perform useful mechanical tasks directly by means of belts or gears to mills, pumps, and other machinery. Detailed studies of potential waterpower sites are unavailable although possible use in terrains where ample water is available was mentioned in several countries. For example, the Instituto Costarricense de Electricidad (ICE) has estimated a small-scale hydroelectric potential as high as two times the potential shown in Table 2-4.**

*See Country Electric Sector Expansion Plans in Volume II.
**ICE, Fuentes de Energia No Convencionales, Costa Rica, Instituto Costarricense de Electricidad, August, 1979.

TABLE 2-4

CENTRAL AMERICA

HYDROELECTRIC POTENTIAL

Country	MW Potential
Guatemala	10,900
El Salvador	1,351
Honduras	2,800
Nicaragua	4,416
Costa Rica	9,000
Panama	2,500
Total	30,967

Source: Julio E. Obiols, The Situation in the Energy Sector in the Member Countries of the Central American Common Market, SIECA/INFRA/79-14, Guatemala, SIECA, November 5, 1979 and German Agency for Technical Cooperation, Ltd.; Master Plan for Electricity Supply, Volume I, Guatemala, INDE, May 1976; and Fuentes de Energia No Convencionales, ICE, 1979.

Geothermal

Most of the Central American countries possess proven or potential geothermal resources. (See Table 2-5.) High heat flow is commonly found in areas of the region's volcanoes and mountains. Exploration and development activities are now being carried out to measure temperatures and conductivities. Geothermal development is the most advanced in El Salvador, where one-third of nonhydroelectric generating capacity is now geothermal. Guatemala, Costa Rica, and Nicaragua are exploring and developing geothermal sites. Guatemala plans a 55-MW facility at Zunil in 1985; Costa Rica similarly plans for a 40-MW plant at Las Hornillas de Miravalles in the same year. Nicaragua is developing the Momotombo site and plans to install a 35-MW plant by 1982. Honduras, and Panama are also investigating several potential sites.

A total electric generating capacity of 500 to 700 MW may be feasible for Central America by 1990, with El Salvador having between 70 to 90 percent of the total.* Use of geothermal resources for other than electrical generating (cooling and heating of buildings, product byprocessing, horticulture, and so forth) would greatly increase resource estimates, but these uses involve special geographic and economic conditions which have not yet been considered in Central America.

A geothermal plant using a condensing turbo-generator of 30-MW capacity was installed in the Ahuachapan field in El Salvador in 1975. Costs reached approximately $500/KW; half of this figure represents the cost of equipment to dispose of geothermal brine. Base-load electricity from geothermal resources, however, is likely

*Ronald DiPippo, Geothermal Power Plants of Mexico and Central America: A Technical Study of Existing and Planned Installations, 000-4051-26, July 1978.

TABLE 2-5

CENTRAL AMERICA

GEOTHERMAL POTENTIAL

Country	MW Potential
Guatemala	1,800
El Salvador	720
Honduras	-
Nicaragua	6,000
Costa Rica	720
Panama	
Total	9,240

Source: Julio E. Obiols, The Situation in the Sector in the Member Countries of the Central American Common Market, SIECA/INFRA/79-14. Guatemala: SIECA, November 5, 1979.

to be less expensive than electricity produced at oil-fired facilities (considering present prices of oil and coal). Moreover, exploration in Central America does not involve serious financial risk due to favorable geological characteristics of the region. Current technology is also available to exploit geothermal fields. It follows, therefore, that geothermal activities will continue to be carried out with good prospects for success.

Petroleum

Petroleum exploration has been undertaken only sporadically in Central America. Guatemala has proven oil reserves of over 10 million barrels,* and is beginning to explore deeper strata which may eventually yield more than 100 million barrels. To date, Guatemala is the only nation in this region with commercially recoverable reserves. The high price of oil should stimulate additional exploration. The high costs and technical requirements of exploration will continue to require the participation of international oil companies.

Coal and Oil Shale

Exploration of potential coal and oil shale reserves is just beginning. Costa Rica has identified some coal resources. Traces of coal in the form of low-BTU lignite have been found in Guatemala and Honduras. In Costa Rica, oil shale reserves have been identified, but not fully evaluated.

Solar

Direct solar energy for crop drying has been used for many years in Central America. Sunlight is intense in most areas, but reliable data on insolation are, in most cases, unavailable or not useful.

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*Direccion General de Mineria e Hidrocarburos, Actualidad Petrolera en Guatemala, Guatemala, DGMH, January-June 1979.

Wind

Although wind energy data are somewhat sparse, the velocity and uniformity of wind at specific high elevation and coastal sites in Central America appear promising. Winds throughout Central America are strongest during the dry season, December through March.

Biomass

Forests cover about one-half of Central America. Total forest and woodland area is over 25 million hectares.* Over half of the coniferous forests are in Honduras, which supplies one half of the timber cut in Central America.

Crops are another aspect of the biomass resource base. All countries in the region have large sugar industries which yield a residue, bagasse, which is already used, albeit inefficiently. Approximately 300-thousand hectares of sugarcane were harvested in 1978.* Large potential biomass resources also exist in the form of crop residues from coffee and bananas.

2.4 Current Energy Use in Central America

Petroleum and non-commercial fuels are the primary sources of energy in Central America. In 1977, petroleum accounted for 55 percent of all energy consumed; non-commercial fuels such as wood and bagasse accounted for an additional 34 percent. Hydro and geothermal power covered the remaining 11 percent.

Table 2-6 shows the breakdown of petroleum consumption for the region in 1977. Of the total petroleum input (304,897 TJ) to the region, 16 percent was imported directly as products, and 84 percent was crude or reconstituted crude locally refined into products.

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*1978 FAO Production Yearbook, Vol. 32, Rome, FAO, 1978.

TABLE 2-6

CENTRAL AMERICA

PETROLEUM CONSUMPTION, 1977

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama[1]	Total
Direct Uses	31,171	27,400	20,241	23,602	25,058	47,195	174,667
Electric Generation[2]	14,165	4,415	3,045	13,228	5,196	21,043	61,092
Total Consumption	45,336	31,815	23,286	36,830	30,252	68,238	235,757
Crude Imports	28,116	32,799	20,594	33,183	15,052	125,460	255,204
Product Imports	22,886	-	3,515	5,252	15,652	2,388	49,693
Total Supply[3]	51,002	32,799	24,109	38,435	30,704	127,848	304,897

[1]Consumption includes the area of the Panama Canal.

[2]In 1979 El Salvador required no petroleum for electric generation; Costa Rica expects to decrease its requirements in 1980 to supply no more than 1% of total generation by public utilities.

[3]The difference between total supply and total consumption is refinery use and uses not accounted for; in the case of Panama, the difference is exports of refined products, over 80% of which are sales of bunker fuel to ships using the Canal.

Note: Petroleum consumption is measured in Terajoules.

Source: See Volume II of this report for country data sources.

With the exception of the refinery in Panama, each of the small refineries throughout the area uses reconstituted crude for feedstock.

Despite the use of semiprocessed crude, imbalances exist between the demand for particular fuels and the output of the refineries. Costa Rica, for example, whose refinery output is about 50 percent residual oil, has to import 73 percent of its diesel needs and 40 percent of its gasoline.* In Guatemala, about 45 percent of total needs are met by direct imports.** El Salvador and Honduras, however, have the capacity to refine all the products they need.*** As hydro and geothermal energy sources replace residual oil in the generation of electricity, large surpluses of this heavy oil will be available. This may force the Central American refineries either to shut down or to invest in more complex processes that increase the yield of lighter products.

Total petroleum imports for the five nations (excluding Panama) grew at a rate of 7 percent over the period 1968 to 1976, with diesel consumption growing at about 8 percent and bunker at about 7.5 percent. Gasoline consumption grew at the slower rate of 5.7 percent per year. More recent data (1977 to 1979) show diesel consumption growing faster due to fuel switching (gasoline vehicles to diesel vehicles) in response to price differentials.

The Economic Commission of Latin America (ECLA)**** and SIECA***** publish the most reliable and systematic time-series data

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*See Table 6-7 of Volume II.

**See Table 2-6.

***See Table 2-6 and Section 4.3 of Volume II.

****CEPAL, Istmo Centroamericano: Estadisticas Sobre Energia, 1977, E/CEPAL/CCE/SC.5/129, Mexico, CEPAL, June 1979.

*****Julio E. Obiols, The Situation in the Energy Sector in the Member Countries of the Central American Common Market. SIECA/INFRA/79-14, 1979.

on domestic demand for petroleum products, particularly demand by economic sector (e.g., industry, transport, households). Although the accuracy of both of these estimates has been questioned, we chose to use ECLA's data when direct sources were unavailable. Data, which include national surveys of non-commercial energy, are now being gathered under the auspices of the UNDP. The resulting energy-balance calculations, to be available at the end of 1980, will provide a firmer analytical base to assess conservation potentials and substitution possibilities.

The electrical sector in Central America operated 2,123 MW of installed capacity in 1977. The breakdown of capacity by fuel type is 42 percent hydro, 55 percent thermal (steam, diesel and gas turbines), and 3 percent geothermal (see Table 2-7). Also, some industries (e.g., sugar mills, mines, cement plants) have their own electric generation facilities. For example, industrial generation capacity is 43 MW in Panama, 25 MW in Nicaragua and 54 MW in Costa Rica. Total energy output of these plants is generally not known, although some industries do provide estimates. Significant additions of hydro electricity capacity are scheduled to come on line between now and 1982 in Costa Rica, Guatemala and El Salvador. This expansion will increase the region's hydro capacity to at least 50 percent of the total.

During the 1960s and earlier, small run-of-the-river hydro-sites provided most of the electricity in the region (except in Panama which was predominantly thermal). The electric demands, increasing from the mid sixties, however, were met by residual oil-fired plants. Large hydro projects with adequate reservoirs became urgently necessary only after 1973. Even then, the high prices commanded by Central American export commodities alleviated the petroleum bill.

TABLE 2-7

CENTRAL AMERICA

ELECTRIC GENERATION AND INSTALLED CAPACITY, 1977

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama[1]	Total
Installed Capacity							
Hydro (MW)	101	232	69	100	224	166	892
Geothermal (MW)	-	60	-	-	-	-	60
Thermal (MW)	294	128	77	205	168	299	1,171
Total (MW)	395	420	146	305	392	465	2,123
Generation (GWh)	1,197	1,238	639	1,074	1,677	1,265	7,090

[1]Excludes the Panama Canal, which has a total of 162 MW (116 MW thermal and 46 MW hydro) with a generation of 118 GWh in 1978.

Source: Country Electricity Companies

Between 1965 and 1975 the yearly growth rate of electric generation for the entire region was 10.6 percent, continuing at 10.5 percent from 1975 to 1977. This represents a per-capita growth rate of 7.1 percent. In 1977, electric generation was to 7,090 GWh, or 302 KWh per capita. The highest ratios are in Panama and Costa Rica (750 to 850 KWh) and the lowest in Guatemala and Honduras (about 160 KWh per capita).

Table 2-8 summarizes total resource consumption for the region in 1977. Hydro and geothermal resource use is expressed in terms of "equivalent of petroleum"; that is, the amount of petroleum that would have been used to generate the same amount of electricity. This convention is applied using 0.25 as a conversion factor. The estimates of firewood and bagasse consumption come from ECLA data. They range from a high of over 40 percent of total resource use in Guatemala and Honduras, to a low of 16 percent in Panama. Preliminary observations from the national surveys conducted by the UNDP energy balances project show that ECLA's estimates are probably low, and that significant adjustments will be made to the figures cited in this report.

The contribution of hydroelectricity is highest in Costa Rica (26 percent) and lowest in Guatemala and Nicaragua (about 3 percent). In El Salvador, hydro and geothermal facilities together contributed 17 percent of total resource use. Petroleum derivatives comprise between 45 and 50 percent of the total in most countries except in Panama, which has the largest urban population and the largest petroleum industry in the region. In Nicaragua, petroleum accounts for 65 percent of total energy consumption because the population is more than one-half urban and because Nicaragua relies heavily on petroleum for electric generation. In Panama and Nicaragua, petroleum represents more than two-thirds of total resource use.

TABLE 2-8

CENTRAL AMERICA

ENERGY RESOURCE CONSUMPTION, 1977

	Guatemala		El Salvador		Honduras		Nicaragua		Costa Rica		Panama		Total	
	TJ	%	TJ	%	TJ	%	TJ	%	TJ	%	TJ	%	TJ	%
Hydro[1]	3,260	3.3	6,944	9.4	6,760	13.0	1,664	2.8	17,899	25.7	7,096	8.0	43,623	9.8
Geothermal[1]	-		5,760	7.8	-		-		-		-		5,760	1.3
Petroleum	51,002	51.0	32,799	44.5	24,109	46.3	38,435	65.0	30,704	44.0	68,062[2]	76.5	245,111	55.3
Bagasse	10,669	10.7	6,109	8.3	2,887	5.5	7,113	12.0	6,524	9.4	4,268	4.8	37,570	8.5
Firewood and Other	34,978	35.0	22,050	29.9	18,326	35.2	11,924	20.2	14,511	20.8	9,540	10.7	111,329	25.1
Total Resource Consumption	99,909	100.0	73,662	100.0	52,082	100.0	59,136	100.0	69,638	100.0	88,966	100.0	443,393	100.0

[1]Expressed in "equivalent of petroleum," (the amount of petroleum that would have been used to generate the same amount of electricity).
[2]Excludes exports.

Source: Summary of data from Volume II of this report.

2.5 Future Energy Use in Central America

2.5.1 Approach and Methodology

The goal of the projections developed in this study was to aid in identifying major Central American energy problems for the future and to analyze alternative energy strategies to meet future needs. The projection methodology was designed to reflect the uncertainties that characterize any analysis of energy futures. These projections serve as instruments for measuring the impacts of alternative energy development strategies rather than as forecasts of the future.

Three forecasting formulae are used, one for each energy category: petroleum, electricity, and non-commercial fuels:

$$\text{Petroleum Energy} = K_1 G^{a_1} P^{a_2}$$

$$\text{Electrical Energy} = K_2 G^{b_1}$$

$$\text{Non-Commercial Energy} = K_3 \cdot (POP)$$

where G = GNP normalized to unity at the time origin of the projection period

P = the price of imported crude normalized to unity at the origin

POP = the population normalized to unity at the origin

K_1 = the petroleum consumption at the origin

K_2 = the electric energy consumption at the origin

K_3 = the non-commercial energy consumption at the origin

a_1 = the income elasticity of petroleum demand

a_2 = the price elasticity of petroleum demand

b_1 = the income elasticity of electric energy demand.

The values for the elasticities and growth rates for each of the variables are given below:

		Case I	Case II
Petroleum:	Income elasticity	a_1 = 1.35	a_1 = 1.00
	Price elasticity	a_2 = -0.32	a_2 = -0.32
Electricity:	Income elasticity	b_1 = 1.50*	

Growth Rates (%):

	GNP (G)	Imported Oil Price (P)	Population (POP)
Guatemala	6.7	5.0	2.87
El Salvador	5.0	5.0	3.02
Honduras	5.0	5.0	3.27
Nicaragua	5.0	5.0	3.23
Costa Rica	5.0	5.0	2.16
Panama	5.8	5.0	2.05

Petroleum Energy

The model for estimating future petroleum demand simultaneously captures the need for increased amounts of petroleum as an economy (G) grows ($a_1>0$) and also the reduction of petroleum use as petroleum prices (P) increase ($a_2<0$). For petroleum projections, we have presented two scenarios throughout this study--Case I and Case II. Case I is the reference case based on historical experience, while Case II assumes a future based on lower petroleum/GNP ratios.

For the Case I reference projections we have used the elasticities derived by Choe and Lambertini for the Latin American and

*Except for Costa Rica and Panama in which national utility forecasts are used.

Caribbean region.* These numbers are consistent with those used in LDC energy projections at Brookhaven National Laboratory.** The income elasticity of 1.35 was derived from historical data and reflects the tendency of countries to increase the energy intensity of their industrial and other activities (per unit of activity or output) as development proceeds.

For Case II projections, the income elasticity was reduced to 1.00. This assumption implies a linear relationship between petroleum use and GNP. In other words, there is no expected increase in petroleum intensiveness with GNP growth.

Given new energy conditions in the world and new perceptions in Central American governments, the next twenty years may actually witness a decided shift from historical experience. For example, economic development may move away from manufacturing towards an agroindustrial base that is generally less energy intensive.*** In any case, the pace of growth in manufacturing in Central America is likely to slow down during the next two decades relative to the growth rate observed during the sixties and seventies. This is because growth rates during the last twenty years reflected growth from an essentially nonexistent industrial base. In addition, the world

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*B.J. Choe and A. Lambertini, "Energy Prospects in Non-OPEC Developing Countries: 1976-1985," August 1978, World Bank Staff Working Paper quoted in Lutz Hoffman, "Energy Demand in Developing Countries: Approaches to Estimation and Projection" in Workshop on Energy Data of Developing Countries, OECD, Paris, 1979.

**See, for example, U.S. Department of Energy, Joint Egypt/United States Report on Egypt/United States Cooperative Energy Assessment, National Technical Information Service. April 1979, Appendix G, Volume 1.

***Although historically the apparent income elasticities in El Salvador, Honduras and Nicaragua have been considerably higher than 1.3, it is to be expected that less energy intensive industrial development strategies will be chosen in the future in those countries.

oil supply has recently motivated many Central American governments to adopt incentives for increased hydroelectrification, or to close gasoline stations on weekends. Also, experience in industrialized economies suggests that significant improvements in efficiency are possible in industrial processes. These favorable developments are, in a sense, outside the control of domestic policy makers, but technology transfer will inevitably lower the ratios between growth in petroleum use and growth in income from ratios observed in the last decades.

The second major influence on national petroleum demand is the price of fuels. For a working hypothesis, we have assumed that the price of petroleum products will increase at a rate of 5 percent per year (in real terms) from 1977 to the year 2000. Starting with a world average price of $13 a barrel in 1977, this hypothesis leads to a price of $25 in 1990 and $40 a barrel in 2000. Since the average world price at the beginning of 1980 may be around $25 a barrel (less than $19 a barrel expressed in 1977 dollars), the hypothesis is probably conservative in the near term. In the longer term, the $40-a-barrel price (in 1977 dollars) is consistent with some estimates of the cost of large-scale alternatives to crude oil such as liquefied coal and ethanol from biomass.

Electric Energy

Because the Central American countries will depend primarily on hydro power for electricity, oil prices will not strongly influence the demand for electricity.*

The formula used above therefore expresses future electric demand as a function of economic development alone. Except for

*There will be an indirect effect due to the effect of oil prices on construction materials, transportation costs and costs of transmission equipment.

Costa Rica and Panama, we use an income elasticity of 1.50.* For Costa Rica and Panama, projections are extensions of the existing figures developed by their national electric companies.

In all instances, electricity growth rates, which range from a low of 6.8 percent a year for Panama to 10.0 percent a year for Guatemala, tend to be high, considering they are to be sustained for over twenty years. However, they are lower than historical growth rates. With the exception of Guatemala, they are no higher than those experienced in industrialized countries during the sixties. Guatemala is exceptional in that the country perceives that large "suppressed demands" are not now satisfied for lack of infrastructure. The existing electrical system is not extensively integrated (therefore, industries with their own generators are still in the process of being incorporated into the grid). Guatemala, of all countries in the region, has the lowest proportion of its population with access to electricity. In a sense, the arguments set forth here to back up the high growth in electrical demand in Guatemala are valid for all other countries, although in a less dramatic way.

Non-Commercial Energy

Non-commercial energy is projected to grow at the rate of population growth. This treatment, although elementary, is consistent with the approach of institutions such as ECLA and SIECA in projecting future energy requirements.

2.5.2 Energy Demand Projections

The energy demand projections which appear in the energy assessments prepared for each country in Central America were developed

*Extracted from the lower range of elasticities presented in B.J. Choe, Demand for Energy and Electricity in Developing Countries: An Aggregate Approach, World Bank, January 29, 1979.

using the methodologies outlined above. The basic projections assume no substitution by liquid fuels other than petroleum-based fuels, and no use of new technologies other than geothermal energy.

Total petroleum demand is projected to grow from a 1977 base of 235,757 TJ (40.8 million barrels) for the entire region, to a total 807,775 TJ (132.1 million barrels) in Case I and 565,075 TJ (92.3 million barrels) in Case II (see Table 2-9). These totals include consumption for electric generation, for industrial transportation, and for use in households. As explained in Section 2.5.1, Case I reflects the historical relation between GNP and petroleum use, while Case II assumes a change in this ratio towards the conditions of more advanced nations.

Petroleum demand is projected to grow at 5.4 percent per year in Case I and at 3.6 percent per year in Case II. The portion of petroleum consumption used directly by the final consuming sectors grows more rapidly, at 6.0 percent per year in Case I, and 4.0 percent per year in Case II. These regional totals, summarized in Table 2-10, are obtained from individual national totals found in Volume II. These levels of petroleum demand, 687,535 TJ (112.4 million barrels) in Case I and 444,835 TJ (72.6 million barrels) in Case II, serve as benchmarks in the analysis that follows in Section 2.6 on the impact of energy strategies.

Future electricity demands follow the pattern of rapidly expanding supply which is characteristic of less-developed countries and reflected in all existing national and international plans. In general, this growth is possible by means of sizable increases in installed hydroelectric capacity. Nevertheless, in four of the six subject countries it appears unlikely that oil-based electricity

TABLE 2-9

CENTRAL AMERICA

TOTAL PETROLEUM DEMAND

	Current 1977/78	Projected, Year 2000	
		Case I	Case II
Guatemala			
TJ	45,336	204,209	141,062
Million barrels	8.3	33.4	23.1
El Salvador			
TJ	31,815	115,521	88,123
Million barrels	5.2	18.9	14.4
Honduras			
TJ	23,286	64,952	43,672
Million barrels	3.9	10.6	7.1
Nicaragua			
TJ	36,830	100,217	75,404
Million barrels	6.3	16.4	12.3
Costa Rica			
TJ	30,254	114,890	74,132
Million barrels	6.0	18.8	12.1
Panama[1]			
TJ	68,238	207,986	145,682
Million barrels	11.1	34.0	23.3
Total			
TJ	235,757	807,775	565,075
Million barrels	40.8	132.1	92.3

[1]Includes the area of the Panama Canal but excludes the sales to ships using the canal, estimated to be about 7 million barrels.

Source: MITRE/E/DI.

TABLE 2-10

CENTRAL AMERICA

PROJECTION OF PETROLEUM DEMAND FOR DIRECT USES

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Total
GNP Growth 1978-2000(%)	6.7	5.0	5.0	5.0	6.0	5.7	
Petroleum Consumption for Direct Uses, 1978 (TJ)	31,171[1]	28,430	20,241[1]	23,602[1]	28,747	47,195[1]	179,386
(million bbls.)	5.1	4.6	3.3	3.9	4.7	7.7	29.3
Growth rate, Case I (Income elasticity = +1.35)(%)	7.4	5.2	5.2	5.2	6.5	6.1	
Growth rate, Case II (Income elasticity = +1.0) (%)	5.1	3.4	3.4	3.4	4.4	4.1	
Petroleum Demand for Direct Uses Case I, Year 2000 (TJ)	161,009	86,721	64,952	75,737	114,890	184,226	687,535
(million bbls.)	26.3	14.2	10.6	12.4	18.8	30.1(2)	112.4
Petroleum Demand for Direct Uses Case II, Year 2000 (TJ)	97,862	59,323	43,672	50,924	74,132	118,922	444,835
(million bbls.)	16.0	9.7	7.1	8.3	12.1	19.4(2)	72.6

[1] Datum for 1977.

[2] In addition, ships using the Canal will purchase some 7 million barrels of bunker.

Source: MITRE/E/DI.

generation will be entirely replaced by hydro and geothermal capacity. Table 2-11 summarizes the electricity projections used in this analysis.

The per-capita GWH consumption grows by a factor of three or more for all countries except Guatemala, where there is a fivefold increase (see Table 2-12). Despite this tremendous growth in Guatemala, its per-capita use will be no higher in the year 2000 than Panama's per-capita use in 1977.* The countries with the highest per-capita use in the region historically (Costa Rica and Panama) are the ones where electricity is projected to grow the slowest, as would be expected at 7.0 and 6.8 percent per year respectively. Nevertheless, by the year 2000 these growth rates translate into per-capita consumption of 2,500 to 2,800 KWh. For purposes of comparison, France did not attain these levels of consumption until the late sixties and early seventies.

Table 2-13 presents a summary of projected energy resource use for the region in the year 2000. As before, geothermal and hydroelectric resources are tabulated at a "fossil fuel equivalent" conversion rate; that is, at the level of petroleum consumption if electricity had been generated with petroleum or other fossil fuels. The conversion used in 0.25 terajoules of electricity per terajoule of fossil fuel.

The projections envision large hydroelectric expansions for Costa Rica, Guatemala and Panama, and smaller ones in Nicaragua, Honduras, and El Salvador. This view of the output of hydroelectricity in a single year, however, does not reflect the different

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*However, the per-capita consumption in the "western," industrialized portion of Guatemala in the year 2000 will be comparable with those of Costa Rica and Panama.

TABLE 2-11

CENTRAL AMERICA

PROJECTION OF ELECTRICITY DEMAND (PUBLIC SERVICE), YEAR 2000

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama[1]	Total
Sales in 1978							
(TJ)	3,740	4,302	1,994[1]	3,098	5,717	5,394	24,245
(GWh)	1,039	1,195	554	861	1,588	1,499	6,736
Growth Rate (%)	10.1	7.5	7.5	7.5	7.0	6.8	
Projected Demand, Year 2000							
(TJ)	34,196	21,118	10,523	16,348	25,965	24,365	132,515
(GWh)	9,499	5.866	2,923	4,541	7,213	6,768	36,810
Projected Generation, Year 2000							
(TJ)	40,242	25,006	12,133	19,403	29,970	28,516	155,270
(GWh)	11,178	6,946	3,370	5,390	8,325	7,921	43,130

[1]Includes former Canal Zone. Note: The difference between demand and generation are transmission and distribution losses.

Source: MITRE/E/DI. See Volume II.

TABLE 2-12

CENTRAL AMERICA

ELECTRICITY GENERATION PER CAPITA, CURRENT AND PROJECTED

(KWH)

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama
Current	157	272	167	348	752	849
Year 2000	839	798	483	1,046	2,465	2,806

Source: Data based on information from national public utilities.

TABLE 2-13

CENTRAL AMERICA

PROJECTED ENERGY RESOURCE USE, YEAR 2000

	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Total
Hydroelectricity[1]	97,704	41,328	43,200	31,680	110,692	90,434	415,038
Geothermal[1]	20,088	29,952	0	21,600	9,836	0	81,476
Petroleum Demand							
For Direct Uses							
Case I	161,009	86,721	64,952	75,737	114,890	184,226	687,535
Case II	97,862	59,323	43,672	50,924	74,132	118,922	444,835
Total Elec. Generation	43,200	28,800	0	24,480	0	23,760	120,240
Non-Commercial Use	87,509	57,996	44,464	39,549	34,386	22,021	285,925
Total Resource Use							
Case I	409,510	244,800	152,616	193,046	269,804	320,441	1,590,217
Case II	346,363	217,399	131,336	168,233	229,046	255,137	1,347,514

[1]Expressed in "Fossil Fuel Equivalent" assuming a conversion efficiency of 0.25

Note: Energy resource use is measured in terajoules (TJ).

Source: MITRE/E/DI.

conditions that exist in these countries. Honduras and Costa Rica appear to have the largest hydroelectric potentials beyond the year 2000, with Panama and Guatemala following next. El Salvador and Nicaragua, however, appear to be more limited and are unlikely to surpass the hydro outputs indicated here.

Geothermal energy is projected to grow to levels of 5-6 percent of total resource use by the end of the century, becoming a significant energy resource in Nicaragua, El Salvador and Guatemala, and less so in Costa Rica. Honduras and Panama are considered to have no geothermal energy within the next two decades.

Petroleum-based electric generation in the year 2000, consuming 120,240 TJ (19.6 million barrels) per year, ignores the possible substitutions that are discussed in the next section.

2.6 Energy Strategies in Central America

The projections presented in the previous section reflect current Central America thinking in energy development. They incorporate the substantial increases in hydro and geothermal capacity being planned today. Nevertheless, the major energy issues confronting the region (i.e., excessive imported oil and diminishing fuel wood supplies), are not resolved through these efforts alone. As shown, imported oil and non-commercial fuel requirements continue to grow through the year 2000.

In this section, future alternatives are suggested in the form of three major Central America energy strategies:

- imported oil substitution,
- conservation, and
- rural energy development

Each of these strategies is discussed and, where possible, each is provided an indication of potential energy benefits.

The context of this strategy presentation is important. First, the orientation is regional. Many energy problems are common to Central American countries. However, there will be differences in strategies as applied to individual countries which are not captured in this approach. To compensate for this, major elements of regional strategies are briefly assessed in country reports in Volume II.

Secondly, the careful development of national energy strategies is a major undertaking clearly beyond the scope of this four-month study. The development of strategies in this report should be seen as a preliminary step, giving orientation to energy development in the region.

2.6.1 Imported Oil Substitution

Table 2-14 summarizes the Case I year-2000 projection of petroleum demand for Central America. Eighty-two percent of the future demand is for the direct use and the rest for utility use. The direct use consists of fuel consumption by industry, transportation and residential/commercial sectors.

The strategy for substitution of this oil, viewed here as an imported oil requirement, contains a number of options:

- discovery and development of indigenous oil reserves
- substitution for oil in electric power generation
- substitution of alternative liquid fuels for transportation
- substitution for oil in industry and commerce

TABLE 2-14

PETROLEUM DEMAND PROJECTIONS FOR YEAR 2000, CASE I

(Terajoules)

	Direct Uses					
	Industrial	Transportation	Residential/Commercial	Total Direct Uses	Utility	Total
Guatemala	33,497	100,280	27,232	161,009	43,200	204,209
El Salvador	36,670	39,166	7,886	86,721	28,800	115,521
Honduras	23,191	35,542	6,219	64,952	0	64,952
Nicaragua	25,569	44,017	6,151	75,737	24,480	100,217
Costa Rica	31,117	77,354	6,419	114,890	0	114,890
Panama	29,589	136,037	3,870	184,226[1]	56,160	240,386
Total	179,633 (22%)	432,468 (53%)	57,777 (7%)	687,535 (82%)	152,640 (18%)	840,175

[1] Includes uses in the Canal Zone.

Source: MITRE/E/DI.

2.6.1.1 Discovery and Development of Indigenous Oil Reserves

Except for recent discoveries in Guatemala, Central America has not yet achieved success in locating economically recoverable oil resources. There are oil exploration activities in each of the countries. However, except for Guatemala, past unpromising drilling results have somewhat dampened the interest and expectations for oil discovery in the area. If recoverable oil can be found, the benefits would be substantial. Not only would the total cost of oil imports drop, but economic growth and the balance of payments conditions would also be improved. This strategy, again, if oil can be found, would be the easiest route to the near-term solution of spending ever increasing portions of export earnings on oil.

Oil exploration is a high-cost and high-risk enterprise. Spending vast resources with little likelihood of results is clearly questionable. However, with the recent dramatic increases in world oil prices, benefits of oil discovery are much greater. Prior oil finds claimed to be "economically unrecoverable" may offer more promise today.

What is suggested is a more structured and intensive approach to oil exploration: careful planning, timetables for exploration, government analysis and interpretation of private company findings, well structured laws for granting concessions, and regulation of drilling and production.

2.6.1.2 Substitution for Oil in Electric Power Generation

Hydro and Geothermal Power

Table 2-15 compares the Case I projected use of hydro and geothermal power for electricity in the year 2000 with the current and near-term expected use of these resources. For the region as a whole, there is substantial untapped hydro potential in the year

TABLE 2-15

CENTRAL AMERICA

HYDRO/GEOTHERMAL ELECTRICITY POTENTIALS AND PROJECTED UTILIZATION FOR 2000 (MW)

	Hydro Potential	Geothermal Potential	Projected Utilization Year 2000
Guatemala	10,900 (101 existing)	1,800 (55 in 1985)	2,430
El Salvador	1,351 (232 existing)	720 (60 existing)	1,474
Honduras	2,800 (69 existing)	No reliable estimates	730
Nicaragua	4,416 (100 existing)	6,000 (35 in 1981)	1,150
Costa Rica	9,000 (290 existing)	720 (40 planned)	1,770
Panama	2,500	unknown	2,249
Total	30,967 (792 existing)	(190 existing or planned)	9,803

Source: See Volume II of this report for country data sources.

2000. Whether these resources are economically recoverable is not evident. Guatemala, for instance, with substantial untapped hydro potential, is planning for thermal electric plants in the period of 1990 to 2000. Future prices of oil and improved resource assessment will determine the extent of this additional hydroelectric potential. Countries like Honduras, with apparent excess hydro capacity in 2000, can provide further oil substitution for its neighbors through sale of electricity across its borders.

In each of the countries of Central America, the opportunity exists for substituting hydro power for small isolated diesel powered generation systems. Work at Instituto de Recursos Hidraulicos y Electrificacion (IRHE), Panama, has shown that the cost savings for this substitution is substantial.*

The continued discovery of geothermal resources for electric generation has not been assumed in our forecasts. Discoveries of extractable geothermal resources will also permit additional substitution of imported oil for electric generation. For this reason, continued geothermal exploration programs are strongly recommended.

Other Electric Generation Options

Bagasse

Another option for displacing oil consumption involves the generation of electricity using bagasse. Bagasse, the residue from sugarcane processing, is burned for electric generation within sugar processing plants. On-site use is very inefficient, however, and there clearly is a potential for generating more electricity from the bagasse than is needed in sugarcane processing operations. Oil substitution strategies should therefore consider the sale of excess bagasse-generated electricity to local utility grids.

*IRHE, Communication with Victor Ossa.

Wood

Isolated communities, without access to the national electricity grid or to hydro electric potential, may be able to substitute wood-fired boilers for the oil-fired or diesel electric systems now in use. This option has potential for communities in eastern Panama and in low lying areas of Honduras.

Solar and Wind Systems

Although solar and wind energy data are not widely available for Central America, preliminary indications show strong potentials for both of these energy options in the region. Countries with limited hydroelectric potential, such as El Salvador, barring substantial geothermal finds, will need to find other electric generation options by the year 2000 if oil use for electricity is not again to be a requirement. Solar thermal and wind electric generation systems are excellent options to pursue. Wind speeds and insolation levels throughout Central America are highest during the three- to four-month dry season when hydroelectric potential may be limited.

The first step in this development is to acquire a reliable data base for wind and solar energy availability throughout the region. As more experience is gained in the construction and operation of these systems throughout the world, installation of pilot plants should also be considered.

Solar photovoltaic systems, although conceptually an ideal way to generate electricity, have limited potential for the near future because of high costs. The future for these systems still rests on the results of current research and development.

Nuclear Power

Nuclear power, because of its extremely high technology and its limitation to large interconnected grids, and the requirements for foreign manpower and materials, is not a recommended option at this time for Central America.

2.6.1.3 Automotive Fuels for Transportation

Table 2-14, presented previously, showed that 53 percent of the projected year-2000 petroleum demand is directed to transportation fuels. It would be very beneficial to substitute for this imported oil also. However, substitution for oil in the transportation section is not as easy as was the case for electric generation. Liquid fuels are virtually essential for transportation.

In this section we discuss two liquid fuel options for Central America--methanol and ethanol.

Methanol

Methanol from woody biomass has significant oil substitution potential in Central America. Table 2-16 indicates that approximately 30 percent of the year-2000 petroleum demand for Central America could be substituted by methanol directly and by synthetic liquid petroleum products derived from methanol. This estimate is based on conversions of 10 percent of annual renewable growth of the forests and woodlands in the region. (See Table 2-17.) The investment cost required is estimated to be $4.8 billion (1976) for 138 methanol plants. This does not include the investment necessary for the subsequent conversions of methanol to synthetic liquid petroleum, which would require additional $2 to $3 billion. The details of this analysis are shown in Table 2-18.

TABLE 2-16

CENTRAL AMERICA

POTENTIAL ANNUAL METHANOL YIELD FROM WOODY BIOMASS

	Methanol Yield from 10% of Forests and Woodlands		
	10^6 metric ton/year[1]	10^9 liters/year	10^{15} joules/year
Guatemala	2.56	3.22	48.4
El Salvador	1.14	1.43	21.5
Honduras	3.13	3.93	59.1
Nicaragua	2.73	3.43	51.6
Costa Rica	1.11	1.39	20.9
Panama	1.81	2.27	34.1
Central America	12.48	15.67	235.6

[1]Based on 0.39 ton methanol/ton of biomass and data in Table 2-17.

TABLE 2-17

CENTRAL AMERICA

WOODY BIOMASS PRODUCTION POTENTIAL

	Forests and Woodlands (10^6 hectares)	Woody Biomass Potential[1] (10^6 dry metric ton/year)
Guatemala	5.8	65.0
El Salvador	2.6	29.1
Honduras	7.1	79.5
Nicaragua	6.2	69.4
Costa Rica	2.5	28.0
Panama	4.1	45.9
Central America	28.3	316.9

[1]Based on 5 DMT/acre-year (Ref: Vol. IV, Silviculture). (11.2 metric ton/hectare)

Source: 1978 FAO Production yearbook.

TABLE 2-18

CENTRAL AMERICA

INVESTMENT COST ESTIMATES FOR
METHANOL PRODUCTION FROM WOODY BIOMASS

	Approximate Number of Plants[1]	Estimated Plant Investment Cost ($\$10^6$)
Guatemala	28	992
El Salvador	13	444
Honduras	35	1,215
Nicaragua	30	1,062
Costa Rica	12	430
Panama	20	701
Central America	138	4,844

[1]Based on 114×10^6 liter/year capacity at $\$35.23 \times 10^6$ investment (1976).

The number of methanol plants can be reduced if a larger plant capacity is assumed, with corresponding reduction in the investment cost. The plant size assumed is equivalent to 114 million liters per year. Smaller plants mean more decentralization and thus would help supply fuels to rural areas.

Once methanol is available, it can be further processed to gasoline. The minimum per-gallon product prices for a wood-to-gasoline fuel cycle are $0.50 for methanol-from-wood and $1.10 for gasoline from wood. These are compared with $1.60 for ethanol-from-corn.* Strategies for using methanol to displace petroleum in the transportation (or any other) sector must take into account the competition for fuelwood among traditional users. For this reason, utilization of crop residues and solid wastes as alternative methanol feedstocks should also be examined.

Ethanol

Ethanol from sugarcane is the second major liquid fuel substitute for petroleum in the transportation sector. Ethanol can be an effective automobile fuel when blended in small percentages with gasoline. The question which each of the Central American countries faces is whether the value of imported oil displaced by ethanol exceeds the expense of ethanol production considering the alternative uses of available land. From a purely technical point of view, large-scale production of ethanol from sugarcane is clearly possible.

Table 2-19 presents sugarcane production data for 1976 through 1978 for each of the six Central American countries. The entire

*R.S. Greeley, Analysis of National Energy Plans, MTR-79W00346, The MITRE Corporation, November 1979.

TABLE 2-19

CENTRAL AMERICA

SUGARCANE PRODUCTION, 1976-1978

	Area Harvested (10^3 hectares)			Total Production (10^3 metric tons)			Productivity (metric tons/hectare)		
	1976	1977	1978	1976	1977	1978	1976	1977	1978
Guatemala	91	82	77	6,845	6,760	5,430	75.2	82.5	70.5
El Salvador	42	41	41	3,170	3,200	3,200	76.2	77.5	77.4
Honduras	50	55	73	1,542	1,845	2,300	30.8	33.5	31.5
Nicaragua	39	42	45	2,300	2,578	2,706	59.5	62.1	66.8
Costa Rica	38	40	44	2,292	2,243	2,437	60.1	55.8	55.8
Panama	30	37	41	1,925	2,396	2,757	64.8	64.6	67.0
Central America	290	297	321	18,074	19,022	18,830	62.3	64.0	58.6
Central America (Average Annual, 1976-1978)		302.7			18,642			61.6	

Source: FAO Production Yearbook, 1978.

region produced an average of 18.6 million metric tons of sugar annually from an area of about 303,000 hectares. This estimate assumes an average productivity of 61.6 metric tons per hectare.

Table 2-20 indicates the potential for ethanol production, based on the sugarcane availability, reflected in Table 2-19. The total sugar crop, if converted to fuel, would yield about 1,231 million liters or 24,160 terajoules of ethanol.

Crude sugar and molasses contribute significantly to export earnings in Central America, so we have postulated a scenario in which the existing sugar industry is left essentially undisturbed and ethanol capacity is developed from the excess production. Accordingly, the second set of figures in Table 2-20 shows a more realistic ethanol-supply potential. The regional production becomes approximately 6,030 TJ (309 million liters) of ethanol. In the year 2000, this amounts to about 1.0 percent of the projected petroleum demand for the region. Ethanol could be used effectively by blending it with gasoline.

Table 2-21 presents data on the estimated capital costs involved in producing 309 million liters a year of ethanol. With fairly small plants of 10,000,000-liter/year capacity approximately thirty-four plants throughout the region would be needed at a cost of about $367 million.*

Electrification of Mass Transit

Although bus transportation in Central America is extensive, oil savings can be achieved with the construction of urban electric mass

*This estimate is based on 180-day/year production and costs made by Schaffer. See p. 49 of MTR-7936, Comparative Economic Assessment of Ethanol from Biomass, The MITRE Corporation, September 1978.

TABLE 2-20

CENTRAL AMERICA

POTENTIAL ANNUAL ETHANOL YIELD FROM SUGARCANE[1]

	100% of Sugarcane Production		25% of Sugarcane Production	
	10^6 liters/year	10^{12} joules	10^6 liters/year	10^{12} joules
Guatemala	419	8,220	105	2,060
El Salvador	211	4,130	53	1,030
Honduras	125	2,460	31	610
Nicaragua	167	3,280	42	820
Costa Rica	153	3,010	38	750
Panama	156	3,060	40	760
Central America	1,231	24,160	309	6,030

[1]Based on average annual sugarcane production--1976-1978 and 66 liters ethanol/metric ton sugarcane.

Source: C. S. Hapkinson, Jr., and J. W. Day, Jr.
MITRE/E/DI.

TABLE 2-21

CENTRAL AMERICA

INVESTMENT COST ESTIMATES FOR FUEL ETHANOL PRODUCTION[1]

	Approximate Number of Plants	Estimated Plant Investment Cost ($\$10^6$)
Guatemala	11	119
El Salvador	6	65
Honduras	4	43
Nicaragua	5	54
Costa Rica	4	43
Panama	4	43
Central America	34	367

[1]Based on 10,000,000-liter/year production.

Source: MITRE/E/DI.

transit systems. The costs and energy savings of such alternatives need to be investigated.

2.6.1.4 Alternative Fuels for Industrial and Residential Commercial Use

The second largest user of imported oil next to the transportation sector in the year 2000 is the industrial sector with 22 percent of the total demand. Residential/commercial use is just 7 percent. Two options for oil substitution are presented in the following sections:

- substitution of electricity for oil
- substitution of direct thermal heat for oil

Substitution of Electricity for Oil

In cases where electricity can be produced from indigenous resources such as hydro and geothermal power, oil use can be reduced by converting heating systems from oil to electricity.

Electric Heating. Oil-fired hot water systems and oil-fired steam process heat systems can be replaced with electric heating systems. In the United States, radio frequency dielectric dissipation (microwave) systems are finding ready application in food processing because the technology offers technical advantages in the interior heating of foods. Other technologies in use include infra-red radiation, freeze drying, direct electric conduction, ionizing radiation, and vacuum drying.*

*Mary Harlow, et al., Survey of Electric Technologies, Technical and Economic Factors Influencing the Selection of Steam or Electric Energy in U.S. Industry, MTR-7209 (McLean, Virginia: The MITRE Corporation, 1976), pg. xxxiii.

Heat Pumps. Industrial electrical heat pumps also offer an opportunity for displacing oil with electricity. Heat pumps are thermodynamic cycles which allow industrial users to recapture waste heat. Industrial heat pumps, for example, can capture and upgrade the heat in the waste stream from a conventional boiler. This heat can preheat feed water to the boiler, thereby saving petroleum or other fossil fuels.

Substitution of Direct Thermal Heat for Oil

Solar thermal. Solar thermal process heat applications can also displace petroleum consumption. Flat plate solar collectors can preheat boiler feed water, or can directly provide low-temperature hot water (about 60° to 70° C). Allowing for a payback period of five to seven years, solar water-heaters are economically feasible in the United States. Moreover, the economic feasibility of applications in Central America would benefit from the relatively higher rates of insolation.

Geothermal. Geothermal energy could be used to displace oil-fired steam plants in a wide variety of low- and medium-temperature process heat applications. The technical feasibility of such applications is well demonstrated. Central American countries should investigate the potential of building industries and industrial parks near proven geothermal resources to take advantage of this resource.

2.6.2 Conservation

Energy conservation is defined as a reduction in the amount of energy required to produce a service or a physical good, in other words, increasing the efficiency with which energy is used. This definition distinguishes conservation from a reduction in service or the output of goods. This is an important distinction because many

third-world policy makers perceive energy conservation as a reduction in growth rates. Rather, conservation is a means of accomplishing higher growth rates with comparable energy inputs or of reducing the energy required (and thus the foreign exchange) for a given rate of economic growth.

The major target for this sort of conservation in Central America is oil consumption. Table 2-22 summarizes the sectoral distribution of oil consumption in the six countries. As indicated in Table 2-22 the major sectors for oil conservation are in industry and transportation.

The Potential for Energy Conservation in Industry

The potential for industrial energy conservation is a function of the types of industries, the types of equipment used in these industries, and the ways the equipment is managed. Lacking such data for the region, we argue by inference.

An idea of the magnitude of savings which may be possible through conservation programs in the industrial sector is suggested by the U.S. "Targets" program. For the period January 1, 1973, to January 1, 1980, the following improvements in energy efficiency were set as targets for ten major industries in the U.S.:

INDUSTRY	IMPROVEMENT TARGET (Percent)
Food	13
Textile Mill Products	25
Paper	23
Chemicals	17
Petroleum Products	20
Stone, Clay and Glass	16
Primary Metals	14
Fabricated Metal Products	25
Machinery	17
Transportation Equipment	18
Weighted Industry Average	17

TABLE 2-22

SECTORAL DISTRIBUTION OF OIL CONSUMPTION

Country	Electricity	Residential-Commercial[1]	Industry	Transportation
	(in percent)			
Guatemala	31	12	14	43
El Salvador	9	8	40	43
Honduras	13	8	31	48
Nicaragua	36	5	22	37
Costa Rica	16	5	22	57
Panama[2]	31	4	7	51

[1]Residential-Commercial includes government.

[2]Distribution presented does not include 7 percent used by the Panama Canal.

Source: Energy Flow Diagrams in Volume II of this report.

According to data for 1979, most industries are expected to meet their targets, and some will exceed them by several percentage points. Analysis of reports submitted to the Department of Energy by industries concerning their conservation activities, as well as forecasts of conservation potential made prior to setting the targets, suggests that the first 10 percent of savings are typically attributable to better management and the balance to programs involving minor capital investment at existing plants.* Major capital programs, including new plants, will not have a large effect on conservation in the seven years to January 1980, because of long lead times for implementation. Savings from "housekeeping" alone are not likely to grow significantly after the early 1980s, while the savings attributable to major new investments will become increasingly important.

Table 2-23 shows comparative international figures for the cement industry. The table illustrates conservation potential in Peru. Fuel and electricity consumption figures compare favorably with other countries. Compared with the "best modern technology," however, energy consumption in several Peruvian plants is quite high. We expect, therefore, that the potential for improved energy efficiency in the cement industry is good, in terms of both improvements at existing plants, and improved efficiency at new plants. The efficiency advantages of new plants may well be compounded as inefficient old plants are shut down. Conservation programs to improve existing plants and to ensure that new plants are properly installed and operated can, therefore, contribute to improving national energy balances.

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*Annual Reports from the U.S. Department of Energy of the "Industrial Energy Efficiency Improvements Program," 1978 and 1979, and technical support work by Gordian Associates, New York.

TABLE 2-23

COMPARATIVE ENERGY INTENSITIES

IN CEMENT PLANTS, PERU & ELSEWHERE

	Kiln Fuel K Cal/Kg. Cement	Electricity KWH/tonne clinker
Peru (1976) Plant A	900	115
Plant B	1440	N/A
Plant C	1215	137
Plant D	1196	135
National Average	1111	137
Germany (1974)	800 - 1200	118
Italy (1974)	900	127
United Kingdom	886	127
United States (1974)	1358	163
"Best modern technology"	850	110 - 120

Source: Phil Palmedo, Pamela Baldwin, et. al., The Contribution of Renewable Resources and Energy Conservation as Alternatives to Imported Oil in Developing Countries, E/DI, 1980.

The U.S. National Academy of Sciences has estimated that cost-effective conservation improvements in U.S. industry could reduce industrial energy consumption per unit of output by as much as 30 to 40 percent by 2000.*

Some of this potential will be realized through current policies or programs through the normal action of market forces responding to higher energy prices. Based on the indirect evidence just reviewed, however, a further reduction of 10 to 20 percent in energy demand in industry could be expected if vigorous conservation programs were instituted.

Transportation

Based on analyses shown in Volume II of this report, transportation accounts for 40 to 50 percent of petroleum use in Central America. In future energy-demand projections we have assumed significant price effects on all sectors, including transportation. There are additional ways, however, in which petroleum use can be reduced beyond expectations from historical trends (on which price elasticities are based). In the transportation sector, two additional categories of improvements can be identified: increased efficiency in the existing fleet and changes in transportation modes.

Fuel efficiency varies widely in automobiles currently available on the new and the used markets. For example, the difference in the fuel efficiency between a 1977 Ford LTD II and a 1977 Honda Civic is almost a factor of three.** A number of policy options, such as taxation, import policies, and maintenance programs could accelerate

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*U.S. National Academy of Sciences, CONAES Study, 1980.

**U.S. Department of Energy, Conservation Strategy, prepared by Office of Assistant Secretary for Conservation and Solar Energy, October 16, 1979.

the move towards a more efficient automotive fleet. Such initiatives could be particularly important in freight transport, which accounts for at least 50 percent of transportation energy use in the region. Without government attention, however, higher fuel costs tend to be passed through to the industries served.

The second general conservation strategy for the transportation sector is to shift toward a more efficient transport mode, particularly from private vehicles to mass transit and from truck to rail. While these strategies may take longer to accomplish, they have an even greater potential impact since the energy efficiency between modes can vary by factors of two to four. Programs to implement such strategies could include investment in efficient urban mass transportation systems (accompanied by disincentives for private car use in urban areas) and modernization and expansion of rail system. Rail systems currently operate at levels well below their potential in most countries in Central America.

Without more detailed evaluations it is impossible to specify the energy savings that could be accomplished with these programs. However, experience in other countries suggests that a reduction in transportation energy consumption of 15 to 25 percent below projected values by 2000 would be feasible with government action.*

Households and Commerce

A relatively small amount of oil is used in the residential and commercial sectors for essential purposes such as cooking. Through the price elasticity used in the projections increases in the efficiency in these sectors have been implied. It is unlikely that further reductions are possible. Nevertheless, government programs

*Based on targets set by the U.S. Industrial Efficiency Improvement Program Administered by the U.S. Department of Energy.

to make households aware of energy conserving methods, and of energy efficient services are important if the projected efficiency improvements are to be achieved.

Electricity

The potential for conserving electricity (and, thus, oil used for its generation) varies a great deal, depending on its particular use. In Central America, the major uses of electricity are lighting, appliances, electric motors, and various industrial uses. The energy demand projections presented in this study assume that there are no incentives to conserve. If such programs were instituted, a reduction in demand of 5 to 10 percent could likely be achieved.

Barriers to Conservation

In discussing conservation strategies, one must identify the major barriers. These are of various kinds:

- low energy prices designed to achieve social or political objectives
- little information on current energy consumption patterns and potential savings through conservation measures
- investment biases towards increased production schemes rather than cost-reduction operations
- lack of government understanding and commitment to conservation
- lack of appropriate technologies
- minimal financial support for conservation measures

Behind all of the conservation strategies lie one or more of these barriers. Efforts to overcome them should begin with general recognition of the potential for energy conservation by the governments of Central America and the development of appropriate policies. Section 3.3 describes recommendations related to conservation measures.

2.6.3 Rural Energy Development

Rural energy use is concentrated in non-commercial fuels, such as fuelwood, charcoal, and bagasse. Given the dispersed nature of fuelwood gathering and consumption, its ultimate use is difficult to quantify. However, it is known that non-commercial energy consumption takes place mostly in the residential sector, rural small industries, and agriculture.

Non-commercial fuels constitute a large proportion of national energy supply. For example, in Honduras and Guatemala, fuelwood contributed 35 percent of total energy input in 1977 (see Table 2-8). Inasmuch as rural energy consumption is large, price and availability of supply have a great impact on the rural economy. Escalating fuelwood prices have had a proportionately larger impact on the income of the poor. Thus, improvements in supply and efficiency of non-commercial fuels have greater significance for the poor than for other income sectors of the population.

Apart from equity, other reasons call for directing attention to the rural sector. Recently Central America has tended toward the expansion of the agro-industrial base. This change from the industrialization efforts of the sixties and early seventies is due, in part, to the dramatic rise in energy costs. Relatedly, during the sixties and early seventies, rural projects were not considered "bankable," so little investment took place in the rural sector.

Solutions to rural energy problems can take many forms. Socio-political reforms, such as changes in rural land tenure, can boost income among those in need. Changes in cultural values can influence the type of technology utilized and the speed with which it is adapted. Financial/fiscal incentives and disincentives can likewise

influence production and income. However, the consideration of technological solutions is most relevant to the energy question.

2.6.3.1. Technological Options for Rural Energy Use

Technological options which are currently available and financially feasible for improving energy use in the rural sector are presented below.

Small-scale hydropower (minihydro) has significant potential for displacing expensive diesel generators in isolated rural areas, providing longer hours of service and, thus, new opportunities for rural inhabitants. For example, in Panama, AID and the Inter-American Development Bank are financing a minihydro demonstration by the Instituto de Recursos Hidraulicos y Electricos (IRHE) in isolated areas. An IRHE official estimated that electricity costs could drop from an average $.16/KWh to less than $.03/KWh with the replacement of diesel by minihydro.* Minihydro can also provide electricity for light and refrigeration in public health posts, for adult education centers, and for other governmental services in isolated areas.

Direct solar probably has the greatest rural applicability, at least in Central America, for the drying of fuelwood and crops such as bananas, coffee beans, and maize. Fuelwood drying can increase the efficiency of burning by 50 percent over that for green wood. Solar crop drying can reduce spoilage and weight, thereby raising producer incomes. Water heating is undoubtedly of marginal economic value, but is perhaps significant in increasing the quality of life in rural areas.

Wind generation of electricity is also a potential energy source, particularly for islands (e.g., Contadora Islands in Panama)

*IRHE, Communication with Victor Ossa.

and coastal areas (e.g., Guanacaste, Costa Rica). Wind power can also be utilized for pumping water and milling grain. For example, a wind machine was constructed, mostly with local materials, and demonstrated to small farmers at the ICADA-Choqui Experimental Station in Guatemala. The Instituto Tecnologico plans a similar pilot project in Costa Rica.

Biogas digesters have been demonstrated in modest numbers, in Guatemala, Panama, El Salvador, and Nicaragua. However, their potential for large-scale use by small farmers in the region is doubtful. Experience in Guatemala shows that the medium-scale and large-scale commercial farmer, with an innovative mentality, who has the access to capital for investment, for significant fertilizer needs, and for ownership of livestock or other sources of biomass, readily adopts this technology. In Panama, coffee processors reportedly are interested in biogas as a profitable means of disposing of coffee wastes. Also, in Panama, the only mechanism by which small farmers have utilized biogas is through an agricultural high school demonstration project. In El Salvador, a rural cooperative successfully pooled local resources to initiate and maintain a biogas plant.

The Lorena stove is an adobe stove constructed with local materials in the highlands of Guatemala. Experiments with it have yielded positive results. In areas where the stove has been introduced, it has reportedly had an overall high level of acceptance. People have perceived several benefits, including the reduction of smoke, savings in wood consumption, elevated cooking, and less effort. However, several barriers have slowed the stove's dissemination including inadequacy of stove-building and maintenance training, cracks due to incorrect mixture of materials, and inability to produce space heating on cold highland mornings and evenings. There is

a need for local participation in stove design and adaptation, especially of women (the principal users), and for increased technical support to overcome design, construction, and maintenance problems.

Technological Options for Rural Industrial Energy Use

A general statement must presently suffice for improvements in the efficiency of rural industrial technology, since little research has been performed in this area. Rural industries, such as brick and lime kilns, bakeries, and small sugar refineries, use large amounts of wood and bagasse to generate heat for baking and cooking. Surveys and research are required to assess the potential for energy options in this area.

2.6.3.2 Technology Transfer to the Rural Poor

In seeking to identify rural energy-delivery mechanisms, attention should be given to experience in the transfer to rural areas of both energy technology and agricultural technologies. The rationale for the transfer of energy technology is obvious. Because institutions involved in general agricultural research and extension often have years of experience in the rural sector, they have insight in effective methods for transfer of information and technology to the rural poor. Moreover, much of the energy technology for the rural poor is agriculturally related.

The similarity of energy outreach to agricultural research and extension suggests that it may be appropriate not only to borrow from the experience of agricultural development programs, but also to complement existing programs.

One place for effective energy outreach is at regional experimental (agricultural and energy) stations. One set of authors

called such an entity in agriculture a "production center"* and described it in terms which apply equally to the concept of energy experimental station.

Important functions of such centers would include:

- operation of an experimental facility with the primary objective of developing and testing technology for the area in which located
- training of farmers and also those engaged in local and station-based research
- providing an operational base for other agencies directly concerned with rural-based technologies.

Similar energy experimental stations exist in developing countries. The U.N.'s Center for Natural Resources, Energy, and Transport, through the U.N. Environmental Program, supports three "rural energy centers" in Mexico, Sri Lanka, and Senegal. These centers perform applied research and provide demonstrations of low-cost technologies using local renewable resources.

To implement strategies for rural energy centers, governments must identify institutions with actual or potential access to the rural poor. Besides agricultural agencies, these might include other government offices, universities, and private institutions. In Central America, academic institutions with an interest in rural energy work include the Universidad Nacional and Instituto Tecnologico in Costa Rica, the Universidad San Carlos in Guatemala, and the National University's Instituto Politecnico in Panama. The Estacion Experimental ICADA-Choqui in Guatemala exemplifies a private effort.

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*World Bank, Inter-American Development Bank, U.S. Agency for International Development, International Agricultural Development Service, Agricultural Research and Farmer Advisory Services in Central America and Panama, Report No. 2348-CA, January 1979, p. 72.

Universities in particular have a role to play in rural economic development. They can educate farmers directly, educate rural youth in applied energy technologies, and provide opportunities for urban students to work in the rural sector.

To be effective, technology transfer must be accompanied by education and participation of the intended beneficiaries. Problems must be mutually defined, and solutions must be mutually generated. Yet, problems often arise in attempting to elicit participation by the local population. Often, cultural barriers of class or ethnic differences, or both, perpetuate indifference. Relatedly, even when the local population is interested, certain values and customs may impede acceptance of a certain technology. Furthermore, the technologies must be demonstrated to be more effective, less risky, and more advantageous than present custom.

Brief discussions with those concerned with rural development in Central America revealed a strong interest in rural energy technologies and the belief, based on field experience, that rural inhabitants were beginning to recognize the energy problem and to seek relief. In particular, the incorporation of energy elements in existing, successful community development projects seemed possible and desirable.

2.6.3.3 Improved Rural Energy Supply

Reforestation. Reforestation is essential to increase the supply of fuelwood available to the rural poor and to rural industries. Especially in areas of high population density and significant deforestation, reforestation projects designed to halt erosion and to provide fuelwood for local use could substantially benefit the rural population. The central highlands of Guatemala, most of El Salvador, the west and center of Honduras, the Pacific coast and central zones

of Nicaragua and Costa Rica, and the central zone of Panama are areas of urgent need.

To simultaneously accelerate reforestation and impede deforestation requires a partnership between private and public interests. This implies that agencies working in reforestation must obtain the participation of the rural population. Education and extension are key elements. The government of El Salvador has had considerable experience in this area. The problems it has encountered and the programs it has developed could be instructive to reforestation agencies in other countries.

In addition to reforestation efforts in process now, reforestation strategies should consider several elements.

- Municipal government could establish community woodlots. National forestry institutes could initiate the projects by educating communities and then gradually transferring skills and responsibilities. The municipal government of Turrialba, Costa Rica, has developed techniques to work with local groups.

- ICAITI could assist in the development of new, energy-efficient technologies for rural industries.

- Forestry professionals (forest rangers, extension agents, etc.) could be educated on a regional basis possibly through ESNACIFOR in Siguatepeque, Honduras.*

Rural Electrification. Rural electrification is an option for increasing rural energy supply which, for the most part, is considered a social program and is almost never financially attractive.

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*This recommendation essentially reiterates one made in a joint AID/IBRD/IDB-sponsored report, Cooperacion Regional para el Desarrollo de los Recursos Forestales, drafted by the Latin American/Caribbean Regional Office, Agricultural Projects Department, IBRD (1977), p. 76.

Utility planners in discussions with MITRE/E/DI teams, expressed little enthusiasm for rural electrification, citing the high costs of transmission infrastructure and hook-up and low electricity usage by the rural poor.

From a utility point of view, this view may be valid. The fact that international financial institution loans often require utilities to maintain certain minimum rates of return may make rural electrification even more unattractive. The question remains whether such thinking is appropriate for developing countries with rich hydraulic potential in an era of increasing scarcity of fuelwood and petroleum. Benefits not measured by the utility's financial analysis may exist: lowered consumption of scarce fuels, decrease in erosion caused by deforestation, release of resources for more productive investments, use of local labor for installation and maintenance of systems (for example, of minihydro).

3.0 RECOMMENDATIONS

One purpose of this report is to assist USAID in the orientation of energy assistance programs in Central America. The approach of the analysis has been to survey the broad energy picture in each country of Central America and to develop potential strategies for resolving the major energy problems. To implement each of these strategies requires resources sometimes unavailable to the Central American countries. These needs are defined in this section. Thus, the recommendations are made in the context of both strategies and needs.

3.1 Central America Energy Development Needs

USAID is member of a larger international community involved in energy development activities in Central America. Included in this group are the World Bank, the Inter-American Development Bank (IDB), the United Nations through the United Nations Development Program (UNDP), the Latin American Energy Development Organization (OLADE), and the Organization of American States (OAS). The roles of particular organizations clearly differ. For instance, large capital-intensive utility projects have usually been financed by the international development banks rather than the Organization of American States or USAID.

To help USAID effectively address Central American energy issues it is important to place recommendations in the context of both the entire scenario of energy needs facing the Central American countries and programs in progress or likely to be supported by other development institutions. Table 3-1 summarizes this information for the Central American countries.

The strategies described in this report are shown in Table 3-2. The last item in the first column is an overall energy planning

TABLE 3-1

CENTRAL AMERICA

ENERGY RESOURCE ASSESSMENT NEEDS

Resource	Guatemala	El Salvador	Honduras	Nicaragua	Costa Rica	Panama	Regional
Hydroelectric, Large-scale					* ●		
Geothermal	*		*	* ●	*	*	
Oil and Gas	*	*	*	*	*	*	
Coal							
Wind	*	*	*	*	*	*	●
Solar	*	*	*	*	*	*	●
Biomass	*	*	*	*	*	*	●
Minihydro Potential	*	*	*	*	*	*	●

* Energy Resource Assessment Needs.

● Target for USAID Support.

Source: MITRE/E/DI.

TABLE 3-2

NEEDS FOR CENTRAL AMERICAN ENERGY STRATEGY DEVELOPMENT

Strategy	Needs	Potential Source of Assistance Support		
		USAID	Other Development Organizations	Private
OIL SEARCH	Proper Legal Structure		*	
	Trained Staff	*		
	Exploration			*
OIL SUBSTITUTION				
Electricity				
Hydro	Resource Assessment	*	*	
	Funds for Construction and Equipment		*	
	Technical Support			*
Geothermal	Resource Assessment	*	*	
	Funds for Construction and Equipment		*	
	Technical Support			*
Small-Scale Hydro	Resource Assessment	*	*	
	Funds for Construction and Equipment	*	*	
	Technical Support	*	*	
Electrification Transportation Industry	Assessment of Potential Benefits	*	*	
	Incentive Development	*	*	
Ethanol	Resource Assessment	*	*	
	Feasibility Studies	*	*	
	Demonstration Plants	*	*	*

TABLE 3-2

NEEDS FOR CENTRAL AMERICAN ENERGY STRATEGY DEVELOPMENT (Concluded)

Strategy	Needs	Potential Source of Assistance Support		
		USAID	Other Development Organizations	Private
OIL SUBSTITUTION (continued)				
Methanol	Resource Assessment	*	*	
	Feasibility Studies	*	*	
	Demonstration Plants	*	*	*
CONSERVATION	Entire Conservation Program Trained Staff Analysis of Conservation Strategies Incentive Programs	*	*	
RURAL ENERGY DEVELOPMENT	Technology Dissemination Programs Isolated Technology Fix Programs Research	*	*	
OVERALL ENERGY STRATEGY	Trained Analysis Staff	*	*	
• Policy Analysis	Adequate Data	*	*	
	Adequate Data Collection System	*	*	
• Research	Research Institution and Staff	*	*	

Source: MITRE/E/DI. Based on personal communication with members of the international development community.

strategy which includes national energy planning, analysis, and policy-making activities. The second column describes the needs concepts. The third column, divided into three categories, lists potential sources of support for the identified needs. Asterisks identify activities in progress; open spaces identify areas for development.

3.2 Potential for Regional Cooperation in Energy Development in Central America

The emphasis of this study is primarily regional. Because many of the energy and economic conditions are common to each country in the region, solutions to energy problems will be similar. There are significant benefits for an integrated approach to common energy assistance programs.

At the same time, the political realities of the region and the potential difficulties for external sharing must be realized. Experience and expectations make it unlikely that countries will cooperate on large-scale, capital-intensive projects. Regional cooperation, however, should be supported to the degree feasible. Such cooperation can realistically take the form of the sharing of energy information and energy-development experience. Recent programs, such as the ROCAP fuelwood project and the UNDP's energy efforts, have demonstrated that countries have more to gain by acting together than by acting separately.

3.3 Recommendations to USAID for Central America Energy Programs

The following recommendations apply to the entire region of Central America. Country-specific recommendations appear in Volume II as refinements and additions to regional recommendations.

1. <u>USAID should support energy analysis and policy-making institutional development in Central America.</u>

In general, overall energy planning and analysis capabilities in Central America lie within the national electric companies. The analyses from these offices are generally oriented to electricity needs. For example, non-conventional resource assessments are performed in terms of fuel sources for electricity generation. Few institutional structures exist or are strong enough to support the assessment and the development of biomass-based liquid fuel systems and nationwide conservation programs.

Therefore, we recommend that USAID encourage the development of energy policy-making institutions. Clearly, the responsibility for deciding the appropriate structure for energy planning institutions rests with individual governments. However, USAID can support the governments' commitments through flexible programs to promote staff education and technical advisory activities. Active staffs of energy economists, energy policy analysts, and energy technology specialists are essential to an effective energy policy-making organization.

2. <u>USAID should support energy conservation program development in Central America.</u>

Conservation strategies have significant potential for contributing to the resolution of the liquid fuels problem in Central America. Despite this fact, essentially no assistance has been given in energy conservation in the region. The value of energy conservation in general, is underestimated in the region. As serious conservation efforts begin, a wide variety of programs may become appropriate (including research on energy conserving equipment, financial mechanisms for conversion). However, given the lack of basic information in this area, and the preliminary state of organizing energy conservation activities, more basic steps need to be taken. Two priority programs are proposed:

a. Energy consumption and conservation analyses

Before energy conservation measures can be developed, better information on energy utilization must be developed. Current UNDP projects to develop national energy balances will provide some useful data; however, the energy balances do not have the appropriate detail for conservation analyses. The major direction of conservation-oriented analyses would be to evaluate both the efficiency with which fuels are now used and the cost-effectiveness of other, more energy-efficient uses. In the industrial sector, this would entail studies at the plant and process level. In the transportation sector, this would include evaluation of the energy efficiency of current and future alternative transportation patterns.

USAID should consider financial and technical assistance in assessing the potential for conservation and investigating possible energy conservation efforts, including pricing and taxation policies.

b. Training and institutional support

Closely allied with the first program is concerted assistance to develop local capacities to assess and promote conservation. The intent would be to place, as far as investment is concerned, increased energy efficiency on a par with increasing output or production of fuels. These areas would include training of personnel in energy conservation analysis, offering technical advice to energy planning groups and energy conservation offices, and providing information on technologies for better energy efficiency. Training for conservation personnel is closely tied to the recommendations for staff training and development within energy policy offices in Central America.

3. USAID should support the development of biomass-based liquid fuels in Central America.

The preliminary assessment of the biomass resource potential for the production of liquid fuels has shown that biomass could

substitute for a significant amount of petroleum imports. USAID can play an effective role in the evaluation and development of this fuel resource. Four programs are recommended.

a. Sugarcane-to-ethanol fuel assessment

Although some work has been done in the development of fuel ethanol from sugarcane in Central America, doubt remains about the economic feasibility of establishing wide-scale ethanol systems in this area. USAID should support an economic assessment of sugarcane to ethanol. This study should be based on an appraisal of Central American conditions such as sugar markets, balance of payments, growing season, transportation, and competition for other land uses. The methodology should be formatted to be easily duplicated from country to country, and the results of the study should be widely disseminated.

b. Sugarcane-to-ethanol demonstration project

The plant in Costa Rica which derives ethanol from sugarcane uses Brazilian technology, and, although Brazil has had numerous years of experience, the financial soundness of this project has stirred considerable debate in Central America. A well planned, energy-efficient operation based on sound economics would be most useful for the regional development of this fuel source. The central feature of this project should be accessibility, so that relevant information can be effectively transmitted throughout the region.

c. Wood-to-methanol fuel assessment

The potential for wood to methanol production is substantial throughout Central America. Moreover, technology is rapidly developing which will permit production of standard liquid fuels such as gasoline and diesel fuel using methanol as an intermediate feedstock.

The first step is to assess carefully the potential of wood to methanol production. Again, USAID should support a study on methanol similar to that recommended for ethanol. This study should examine markets for Central American wood products and their effects on the balance of payments. The study should evaluate the economics of the production process and the national impact in the use of methanol both as a fuel and as a way of producing synthetic gasoline and diesel fuels. The environmental effects of large-scale use of existing forests and the transportation requirements should also be included in this investigation.

The results should be distributed widely in the region. Regional conferences on the subject of methanol fuel would also be useful for disseminating information.

d. Wood-to-methanol demonstration project

Based on the feasibility of wood-to-methanol fuel systems, USAID should consider funding one or more demonstration facilities in Central America.

4. USAID should support rural energy programs in Central America.

USAID should place greater emphasis on energy problems in the rural sector through a number of mechanisms such as:

a. Establishment of energy demonstration and extension centers

Energy demonstration and extension centers speed the spread of low-cost energy technologies (solar, wind, small-scale hydro, biogas, etc.) to individuals and communities. Energy centers could be established through a given country's public or private entities, such as community development agencies, universities, agricultural extension agencies, cooperatives and national cooperative agencies. The Peace Corps might be able to work through one or several of these

institutions, possibly with USAID funding. From these centers, trained extension agents or community development workers would be able to offer individual and group instruction in the appropriate technologies.

Such a strategy requires the strengthening of designated organizations working in the rural sector through addition and improvements in staff, improvements in organization, clarification of responsibilities, and capital inputs. Some agencies, for example agricultural research agencies, face difficulties in fulfilling their primary mission, let alone expanding into the energy field. Therefore, we would caution against placing sole responsibility for energy extension services onto one organization.

b. Strengthening of National Forestry Institutes and National Reforestation Programs

USAID should support measures to improve forestry staff capabilities, especially field personnel. Support of staff training could be in the form of in-country short courses at regional centers such as ESNACIFOR in Honduras.

c. Support of community energy projects

USAID should continue to support locally initiated energy projects that have the potential for improving rural community energy use, living conditions, etc. USAID's mission use of the funds for special development activities for these purposes is encouraged.

d. Training and education in rural energy-related technology

An effective means to incorporate new ideas into rural areas is through the direct participation of local people. This kind of acceptance requires the support of well respected leaders within the community. USAID should assist rural energy education programs which

strive to transfer energy technology in this manner. A number of approaches are available:

- training of agricultural extension agents in rural energy technology installation and use
- development of materials on applied energy technologies which could be incorporated into high school curricula, such as Panama's Ciclo Basico program

5. USAID should support renewable energy resource assessments in Central America.

Information on wind, solar, biomass, and mini-hydro potentials in Central America is limited. Solar data do not appear to be consistent across countries and, sometimes, between stations. Biomass and wind data are rarely available in forms suitable for energy purposes. Hence, uniform measuring systems would be useful to each country.

USAID should support the development of uniform methodologies for renewable energy resource evaluations. If longer term governmental support of renewable energy measurement and assessment programs is expected, USAID should consider, instead, capital and technical support of these programs.

6. USAID should support innovative energy research in Central America.

USAID should be aware of interesting new energy ideas within countries and encourage the development of these ideas. Based on our experience with research projects in Central America, funding of certain ventures develops public interest in energy problems and solutions, encourages innovation, and in some cases, results in interesting energy solutions. We recommend funding of appropriate energy research projects.

3.4 Recommendations to USAID on Mechanisms for Regional Energy Program Development

Although the energy programs just described are directed to all of Central America, each program must be aimed toward energy development within specific countries. For instance, an ethanol plant might be built in Panama, or an energy research project developed in Honduras. The regional cooperation will occur because of communication of energy development results and experiences. In this section we recommend how USAID might effectively guarantee that this communication take place.

1. USAID should require that major USAID energy projects include programs for regional dissemination of results.

Recipients of USAID R&D funding should be required to establish appropriate mechanisms for disseminating resulting information. These mechanisms could include presentation of results at regional conferences, project demonstration tours, and instruction of technicians. This requirement will not only increase the information dissemination, but also improve the quality of the projects because of peer review.

2. USAID should support regional energy conferences on specific energy development needs.

USAID should encourage the gathering of energy development specialists from the Central American countries to report and share their country's energy developments. Energy development conferences should cover:

- energy data collection and analysis
- fuelwood use
- conservation program development
- ethanol/methanol development
- rural energy development
- oil substitution activities

3. USAID should support regional energy training programs.

The experience gained in specific energy-related areas in one or more countries can be of significant value to other countries in the region. The MITRE/E/DI team recommends that USAID confirm the importance of training programs through financial support. Programs could include:

- hydrocarbon management
- forest management
- energy conservation
- biomass energy production

Central American specialists should organize and implement such programs. When appropriate, other experts could be invited to participate.

4. USAID should investigate the potential for a Central American energy information dissemination system.

To assist Central America in the transfer of energy information, USAID should study the potential benefits and mechanisms of a regional energy-information network. Mechanisms could possibly be a periodical with articles from each of the countries on current energy developments and an extension of the NTIS system with special procedures used to define Central American energy publications.

5. USAID should continue to support regional energy institutions such as SIECA/COMENER, ICAITI, and CATIE.

Central American regional institutions offer a focal point for common Central America energy and energy-related programs. ICAITI and CATIE have research capabilities which can be used effectively for the investigation of local energy problems. Imported techniques often require modifications, and these institutions can effectively deal with these difficulties. They have staff, facilities, and

technical expertise which can not be easily duplicated on a country-by-country basis. Providing these institutions with financial support will increase their ability to provide development assistance in Central American energy development programs.

APPENDIX A

CONVERSION TABLES

APPENDIX A - CONVERSION TABLES

Energy Equivalents to Energy Units

By Definition:

1 metric ton of oil equivalent (toe) = 10^7 Kcal[1]

1 thousand tons of oil equivalent (mtoe) = 41.84 Terajoules (TJ)

1 mtoe = 11.62 gigawatthours (GWH)

Based on the Above Definition

Crude Oil:	1 Barrel	=	0.146 toe
Gasoline:	1 Barrel	=	0.132 toe
Kerosene:	1 Barrel	=	0.143 toe
Diesel:	1 Barrel	=	0.147 toe
Residual:	1 Barrel	=	0.158 toe
LPG:	1 Barrel	=	0.101 toe

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[1] Also found in the literature are these equivalences:

1 toe = 10.5×10^6 kcal

and

1 toe = 10.7×10^6 kcal

Physical Units to Energy Units

			Million Joules
Crude Oil:	1 barrel	=	6120
Petroleum Products--			
LP gas (propane/butane):	1 barrel	=	4230
Gasoline:	1 barrel	=	5540
Kerosene and jet fuel:	1 barrel	=	5980
Distillate (diesel, gas, oil, heating oil, No. 2 oil):	1 barrel	=	6145
Residual (heavy oil, bunker oil, No. 5-6 oil, fuel oil):	1 barrel	=	6630
Other:	1 barrel	=	6120

Energy Units to Energy Units

1 KWh = 3.6 million joules
1 GWh = 3.6 Terajoules (TJ)
1 Btu = 1,055 joules
1 Kcal = 4,184 joules

Miscellaneous

Volume:

1 m^3	=	6.296 bbls.
1 m^3	=	35.31 cubic feet
1 barrel	=	42 gallons
1 barrel	=	159 liters
1 gallon	=	3.785 liters
1 cubic foot	=	28.32 liters

Other:

1 barrel per day	=	365 barrels (per year)
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 B

CENTRAL AMERICAN CONTRIBUTORS TO THIS STUDY

APPENDIX B - CENTRAL AMERICAN CONTRIBUTORS TO THIS STUDY

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