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BROOKHAVEN NATIONAL LABORATORY DEVELOPING COUNTRIES ENERGY PROGRAM

A PRELIMINARY ASSESSMENT OF ENERGY SUPPLY AND CONSUMPTION IN THE DOMINICAN REPUBLIC

Gordon McGranahan, Glen Mitchell,
Vinod Mubayi, and Robert Stern

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DIVISION OF REGIONAL STUDIES
NATIONAL CENTER FOR ANALYSIS OF ENERGY SYSTEMS
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

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**GORDON MCGRANAHAN, GLEN MITCHELL,
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PREFACE AND ACKNOWLEDGMENTS

Recent events affecting the cost and availability of energy have focused attention on the need to understand in greater detail how energy is used, directly and indirectly, in the agricultural and food systems of developing countries. This energy overview of the Dominican Republic, initiated and sponsored by the U.S. Agency for International Development (USAID), attempts to meet that need by providing not only an analytical base for evaluating initiatives that are likely to be applicable to many developing countries but also an improved basis from which U.S. assistance policy can be made.

The authors profited immensely from the comments of Charles Blankstein (U.S. Aid Mission to the DR) and were assisted greatly by the help of Manuel Canario and Joaquim Santaella (INDOTEC), Jose Ramon Acosta (Dominican Republic Energy Commission), and Gerhard Tschannerl (Consultant to BNL). The authors of the report are solely responsible for its content, however.

The preparation of the report was carried out by Patricia Miller.

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TABLE OF ACRONYMS

BA -	Agrarian Bank
CALA -	Commission for the Application of Agrarian Laws
CAT -	Tax Payment Certificate
CDE -	Electricity Corporation of Dominica
CEA -	State Sugar Council
CEDOPEX -	The Dominican Center for the Promotion of Exports
CENDA -	National Agricultural Development Center
CFI -	Industrial Development Corporation
CNIECA -	The Center for Agricultural Research and Extension
CORDE -	State Enterprises Corporation
CODIA -	Dominican College of Engineers, Architects and Surveyors
CRIES/SIEDRA -	Comprehensive Resource Inventory and Evaluation System of Agriculture
DCV -	Rural Road Directorate
FAD -	Food and Agricultural Organization (United Nations)
FIDE -	Economic Development Investment Fund
IAD -	Dominican Agrarian Institute
IDB -	Inter-American Development Bank
IDECOOP -	Institute of Development and Cooperative Credit
IDSS -	Dominican Social Security Institute
INAZUCAR -	National Sugar Institute
INCAP -	Institute of Nutrition for Central America and Panama
INDRHI -	National Water Resources Institute
INESPRE -	Price Stabilization Institute
IICA -	Inter-American Institute of Agricultural Sciences
ONAPLAN -	National Planning Office
ONAPRES -	National Budget Office

TABLE OF ACRONYMS (continued)

PCI -	Practical Concepts Incorporated
RPUS -	Resource Production Units
SEA -	Secretariat of Agriculture
UNDP -	United Nations Development Programme

SUMMARY

This report presents a preliminary description of the Dominican Republic's energy resources, its recent energy supply-demand pattern, and some energy demand projections for the years 1990 and 2000.

- Of approximately 129 quadrillion joules of energy consumed in 1977, 66 percent was attributable to commercial fuels. Oil is the most important energy source, accounting for about 64 percent of the country's total energy consumption in recent years.
- Total energy consumption grew at an average annual rate of 8 percent between 1970 and 1977. During the same period, per capita energy consumption increased from 18.5 billion joules to 25.9 billion joules (about 5 percent per year).
- Industry is the largest energy consumer, accounting for about 46 percent of total energy consumption in 1977. Public Utilities accounted for another 19 percent, followed by the residential sector with 18.6 percent and transportation with 14.3 percent.
- In the absence of any domestic production, the Dominican Republic has had to rely on imports to satisfy all of its oil requirements. Between 1971 and 1974 the value of imports of petroleum and petroleum products increased sixfold. However, with the installation of the Haina refinery (11 million barrel capacity), the composition of petroleum imports has changed significantly; with the exception of fuel oil, refinery production has displaced most of the petroleum-based fuel imports.
- The Dominican Republic is not very well endowed with energy resources. There is some indication that oil and geothermal resources exist, but it appears unlikely that they will contribute significantly to the national energy system, at least in the near future. With respect to the country's hydro potential, fifty sites, as of 1976, had been identified with a total capacity of approximately 1 GWe and an electricity generation capability of 2,500 GWh per annum. Noncommercial energy resources such as bagasse, wood, and charcoal are relatively abundant but a great portion of the accessible forest lands has been depleted. Although the level of solar radiation is relatively high, it is a virtually untapped energy source. Under current conditions wind energy does not appear to be significant except in isolated locations.
- To provide a "Reference Case," commercial energy demand is projected without explicit consideration of the effect of rising energy prices. With a GDP growth rate of 6 percent per annum, commercial energy demand is projected to grow to 228.1×10^{15} joules in 1990 and 486.5×10^{15} joules in 2000. The sectoral composition of commercial energy demand in 2000 is 40 percent industrial, 34 percent public sector electricity generation and transmission (net of sales), 19 percent transportation, 5 percent residential, and 4 percent other uses. Oil alone is projected to account for about 95

percent of commercial resource use in the year 2000 (the remainder being hydro).

- A second case, incorporating a price elasticity of 0.3 for commercial energy demand and an annual growth rate of real energy prices of 4 percent per annum, projects commercial energy demand to grow to 195.7×10^{15} joules in 1990 and 371.2×10^{15} joules in 2000. The share of oil in total resource use in the year 2000 is 94 percent.
- Two of the major noncommercial fuels, wood and charcoal, are projected to supply about 20.7×10^{15} joules of fuel energy in the year 2000 of which 16.7×10^{15} joules are destined to rural cooking. Bagasse is projected to supply 59 to 75×10^{15} joules, while other crop residues and animal waste could potentially supply an additional 16.3×10^{15} joules and 113×10^{15} joules respectively. (The potential role of noncommercial fuels in the energy system is smaller than these figures may imply because of the low end-use efficiencies and collection problems.)

1. INTRODUCTION

1.1 GENERAL DESCRIPTION

The Dominican Republic, the second largest Caribbean country with a land area of 48,734 square kilometers* (about the size of Maryland and New Hampshire combined), occupies the eastern two-thirds of the island of Hispaniola. It is bordered on the north by the Atlantic Ocean, on the east by the Mona Passage which separates it from Puerto Rico, on the south by the Caribbean Sea, and on the west by Haiti.

With an estimated population of 4.98 million in 1977,¹ the Dominican Republic (DR) is the fourth most populous country in Central America.² The average annual population growth rate is relatively high at about 2.9 percent from 1970-76.³ The rural-urban split is fairly even with about 46 percent⁴ of the population living in urban areas mostly in and around the big cities of Santo Domingo in the central region and Santiago in the north. Between 1960 and 1975 the population of these two cities grew at an average annual rate of more than 6 percent.⁵ The rate of population increase for other urban areas over the same period ranged from 3.8 percent in Mao to 7 percent in San Pedro de Macoris.⁶

The Cordillera Central and three other parallel mountain ranges (Cordillera Septentrional, Sierra de Neiba, Sierra de Baoruco), all running in a northwesterly direction, dominate the highland topography⁷ in the western part of the country, while the Cordillera Oriental, a narrow band of hills and somewhat less imposing, is the principal mountain system in the east. Running some 200 kilometers across the republic with its rugged slopes, convoluted ridges, and extensive pine forests, the Cordillera Central virtually divides the country into two parts. Its highest peak, Pico Duarte, is the tallest in the West Indies rising to some 3,175 meters above sea level.

The Cordillera Septentrional which lies north of the Cordillera Central is a much smaller mountain range characterized by precipitous slopes and deeply etched valleys. Rising in the west near the town of Montecriste and extending as far east as the swamps surrounding the mouth of the Yuna River near the Samana Peninsula, its highest point of elevation measures some 1219 meters.

The Sierra de Neiba and the Sierra de Baoruco both lie south of the Cordillera Central. Rising in the southwest near the Caribbean Sea, they both extend northwestward into Haiti where they join related ranges. Both have peaks as high as 1829 meters and crest generally at elevations of between 915 and 1220 meters.

Like the highlands which define them, the country's lowlands (the Cibao Valley, the San Juan Valley, and the Neiba Valley) stretch in a parallel northwesterly direction from origins close to the Caribbean to adjoining valleys in Haiti. The most famous of the lowland areas, the Cibao Valley, is the breadbasket of the country. Situated between the Cordillera Septentrional and the Cordillera Central, the Cibao covers some 5180 square kilometers

*Including 119 square kilometers of adjacent islands (Beata, Catalina, Saona, Alto Velo, Catalinita) in the Caribbean Sea.

Source: Area Handbook for the Dominican Republic, U.S. Government Printing Office, Washington, D.C, 1973.

Figure 1. Map of Dominican Republic

(about 10 percent of the national territory) from Samana Bay in the east to the Haitian border in the west. This is where population density is greatest. The Eastern Cibao Valley (known as the Vega Real or the Royal Plain), for example, especially the region between the cities of Santiago and San Pedro de Macoris, is estimated to have densities exceeding 240 persons per square kilometer.

The San Juan Valley which is located between the Cordillera Central and the Sierra de Neiba covers an area of some 1820 square kilometers. Most of the people in this region are engaged in cattle raising and in rice, bean, and coffee production.

The other parallel valley, the Neiba (known also as the Enriquillo Basin), lies north of the Sierra de Baoruco. This is a low-lying plain occupying some 1950 square kilometers of semiarid land mostly in the area known as the Cul de Sac of Haiti. Its most distinctive landmark is the large salt lake, Lago Enriquillo, which is 44 meters below sea level and is considered the lowest lake in the West Indies.

The other major lowland area, the Caribbean Coastal Plain, is located in the eastern part of the country near the foothills of the Cordillera Oriental. The primary activities in this region which covers more than 2860 square kilometers are cattle raising and sugar production.

1.2 ECONOMY

The International Monetary Fund (IMF) estimates the Dominican Republic's (DR) GNP at \$4.34 billion and GNP per capita at \$872 in 1977.⁸ In the same year GDP was estimated at RD \$4.46 billion at current prices* and RD \$2.54 billion⁹ at 1970 constant market prices. The sectoral composition of the GDP and the 1973-77 growth rates of the individual sectors are shown in Table 1.

The agricultural sector in the DR is comprised mainly of those activities having to do with the production of food crops. Activities having to do with livestock production, fishing, and forestry are not viewed by the authorities as part of the agricultural sector as is the case in some other developing countries but as activities for separate sectors of the economy.

The agricultural sector which has grown at an average annual rate of 0.7 percent during the period 1973-77 produces two main types of crop - those principally for exportation and those principally for domestic consumption. Cane sugar, tobacco, coffee and cocoa are the main export crops while rice, corn, peanut, red beans, cassava, plantain, and tomatoes are some of the more important ones consumed locally.

Of all agricultural crops, sugar is and has been the most important, not only in terms of its contribution to employment and to GDP¹⁰ but also in terms of export income. It led all other commodities in volume of exports in 1977 and was by far the top earner of foreign exchange in that same year. More than 1.1 million tons of sugar valued at \$218.3 million¹¹ were exported representing an average annual growth rate of 11.1 percent from 1970. Over the same period which saw very high world market prices in 1974-75 and extremely

*The rate of exchange was U.S. \$1.00 = RD \$1.00 (1 Peso).

TABLE 1
DOMINICAN REPUBLIC
PERCENTAGE DISTRIBUTION OF 1977^P GDP AT CONSTANT
1970 PRICES AND SECTORAL GROWTH RATES

Sector	Percent	Average Annual Growth Rate, % 1973-1977
Agriculture	11.3	0.7
Livestock	5.4	3.5
Forestry/Fishing	0.4	- 4.2
Mining	5.6	9.2
Manufacturing	18.4	5.3
Construction	7.2	7.4
Commerce	16.7	5.7
Transport	7.3	7.0
Communications	1.0	12.4
Electricity	1.5	10.6
Money and Banking	2.3	15.2
Ownership of Dwellings	6.7	7.2
Government Services	7.4	4.5
Other Services	8.8	5.4
Gross Domestic Product	100.0	5.5
GDP per capita	-	2.4

P = preliminary figures.

SOURCE: Reference 9, pp. 181-183.

low ones in 1976 and 1977, the volume of exports grew at an average annual rate of 5.3 percent.

Since its introduction into the DR in the early part of the eighteenth century, coffee has become one of the more important crops.* Of the 120,416 tons¹² produced in 1977, mostly on small farms in Barahona, the Cibao Valley, and the Ocoa River region, more than 79,000 tons valued at \$169.5 million were exported which is more than twice the 1976 export volume and almost a threefold increase since 1970.¹³

Although the volume of cocoa exports increased by only 4 percent from 1976 to 1977, the value of exports increased more than 209 percent during the same period. Export volume amounted to 24,612 tons in 1976 and only 25,615 in 1977 while the value of exports jumped from RD \$43.37 million to RD \$93.06

*Almost all of DR's coffee is of the "arabica" variety, the world's most popular type. Some coffee of the "robusta" type is produced but not in any significant quantities.

million.¹⁴ This no doubt was a reflection of the dramatic increase in cocoa prices; for example, the price of cocoa went from U.S. \$65.75 (fob) per 100 pounds on the New York market in January 1976 to U.S. \$209.3 in July 1977.¹⁵ The DR is not a signatory to the International Cocoa Agreement of 1975 although it is one of the major producing countries¹⁶; therefore it is not restricted by price and quota regulations under the agreement.

Of all the main export crops, tobacco has been the most seriously affected by fluctuations in foreign demand. In addition, the outmoded techniques used in its production and the marked inequalities surrounding the distribution of its profits have, at least in some sections of the country, contributed greatly to the steady decline of the crop.¹⁷ In 1960, 15,193 tons of tobacco valued at RD \$6.73 million were exported. By the end of the next decade export volume had reached only 19,535 tons. Although export volume increased sharply in 1975 (37,137 tons) and 1976 (32,798 tons), most of the 1970's saw relatively low levels of exports. In 1977, for example, only 18,686 tons reached foreign markets, mostly Spain (62 percent), United States (9 percent), Belgium-Luxembourg (6 percent), and Holland (5 percent).¹⁸ Tables 2 and 3 show main export commodities for 1974-77, their value, volume, and country of destination.

Because the DR is a deficit-producer of basic foodstuffs it needs, the authorities* must import in order to meet internal demand.¹⁹ The reduction of imports via domestically produced substitutes is therefore an understandable policy goal of the government²⁰ and a clear indication of the importance of those crops that are produced primarily for local consumption.²¹

Rice is the most important staple not necessarily because of its nutritional value but mainly because it is the food most preferred by

TABLE 2
DOMINICAN REPUBLIC
EXPORT VALUE OF SELECTED COMMODITIES, 1974-1977
(Millions of RD \$)

Commodities	1974	1975	1976	1977
Sugar	324.12	552.13	247.09	218.32
Coffee	39.29	34.70	83.30	169.54
Cocoa	44.23	24.77	44.37	93.06
Tobacco	39.00	34.40	38.26	27.12
Ferronickel	93.09	102.14	110.33	91.92
Bauxite	17.75	16.72	15.52	21.98

Source: Data (market value) for 1974 from Reference 9, pp. 109-112. Data (fob value) for 1975-1977 from Reference 11, pp. 17-19.

*The Price Stabilization Institute of Instituto de Establizacion de Precios (INESPRE) is responsible for most of the government's import activities, and as of March 1976, supported the prices of eight crops - rice, red and black beans, corn, sorghum, coconut, copra, garlic, and onion.

TABLE 3

DOMINICAN REPUBLIC

EXPORT VOLUME OF SELECTED COMMODITIES AND COUNTRIES OF DESTINATION

Commodity and Country	1974 ^c		1975		1976		1977	
	Volume (metric tons)	%	Volume (metric tons)	%	Volume (metric tons)	%	Volume (metric tons)	%
Sugar ^a	1,015,744	100.0	938,785	100.0	963,270	100.0	1,101,040	100.0
United States	718,281	70.7	684,648	72.9	895,083	92.9	881,331	80.0
Italy	-	-	54,975	5.8	-	-	-	-
Romania	-	-	31,992	2.4	8,205	0.8	-	-
Kenya	-	-	-	-	14,980	1.5	-	-
Morocco	-	-	29,965	3.1	-	-	63,236	5.7
Coffee ^a	31,137	100.0	25,642	100.0	35,248	100.0	79,751	100.0
United States	25,563	82.0	21,980	85.7	31,851	90.3	76,281	95.6
Belgium-Luxembourg	1,148	3.6	1,337	5.2	796	2.2	458	0.5
Puerto Rico	-	-	-	-	967	2.7	2,113	2.6
Cocoa ^a	26,560	100.0	21,668	100.0	24,612	100.0	25,615	100.0
United States	26,126	98.3	21,507	99.2	24,612	100.0	25,201	98.3
Ferronickel ^a	79,839	100.0	63,066	100.0	68,139	100.0	59,947	100.0
Holland	36,907	46.2	36,585	58.0	28,847	42.3	27,084	45.1
United States	38,236	47.8	17,062	27.0	26,050	38.2	27,453	45.7
Canada	-	-	4,524	7.1	11,346	16.6	-	-
Bauxite (metric tons) ^b	1,473,588	100.0	909,906	100.0	627,152	100.0	774,098	100.0
United States	1,473,588	100.0	909,906	100.0	627,152	100.0	774,098	100.0
Tobacco ^a	42,326	100.0	37,137	100.0	32,798	100.0	18,686	100.0
Spain	22,398	52.9	15,855	42.6	19,421	59.2	11,731	62.7
United States	4,347	10.2	4,315	11.6	3,351	10.2	1,689	9.0

^aData from Reference 11, pp. 17-19.^bData from Reference 9, p. 115.^cData from Boletín Mensual, p. 113, August 1978.

Dominicans, especially those in the rural areas.²² The importance of rice is even more evident when one looks at the number and value of loans made to the rice subsector by the Dominican Development Bank in 1975.²³ From January to September, 51 loans amounting to RD \$543,337 were made to rice projects; this represented 23.3 percent of the number and 28.16 percent of the value of all loans made during the period. Despite the disastrous drought which affected not only rice but all other crops that year,²⁴ output of rice reached almost 290,000 tons in 1977, an increase of 11 percent from 1974 and almost 33 percent from 1975.²⁵ This, however, was not sufficient to meet domestic demand and INESPRE was forced to import more than 56,000 tons at a cost of RD \$17.04 million (fob).²⁶

With respect to intake (grams) of the various foods, plantain leads the field in both urban and rural areas. An unpublished 1973 consumption survey by the Secretariat of Agriculture indicated that urban and rural per capita daily intake of plantains was 192 and 182 grams respectively, compared to the figures of 160 (urban) and 174 grams (rural) for rice. An earlier survey had also indicated the dominance (intake) of plantains in the Dominican diet.²⁷

Nutritionally, beans, especially kidney beans which are the most commonly grown variety, are of great importance to the rural population. Among the common foods, they rank first as the available source for proteins and iron, second for calcium and thiamine, and third for riboflavin.²⁸ Kidney beans production was about 40,264 tons in 1977, a 10.6 percent drop from the 1976 figure and an 18.3 percent decline from the bumper year 1974.²⁹ This required imports totaling 4,872 tons in 1977 in order to satisfy internal demand; consumption in that same year amounted to 43,624 tons.

As a result of expansion in the livestock industry over recent years, corn has become increasingly more important. Frequently interplanted with other crops, especially beans, it is by far the primary feed* utilized in animal production. In 1977, corn production was only 54,152 tons (967,000 quintales) - the first time since 1973 that output amounted to less than 56,000 tons (1 million quintales).³⁰ While human consumption of corn since 1973 has remained relatively constant, in absolute terms, imports of corn along with animal consumption of the crop have been steadily increasing. Human consumption of corn ranged from 7,224 tons in 1973 to 8,344 tons in 1977 while the corresponding figures for animal consumption were 113,288 and 129,920 tons; and for imports - 66,976 tons in 1973 and 92,400 tons in 1977.³¹

Cassava (yuca) is the major root crop in the Dominican diet, especially for lower income families. Of the 183,680 tons produced in 1977, almost 172,660 tons (94 percent) were consumed locally by humans, 7,347 tons (4 percent) by animals, and only about 2 percent were exported.³²

Table (salad) as well as industrial tomatoes are grown in the Dominican Republic mostly on farms that are less than 3 hectares in size and on which relatively high levels of capital intensive techniques are used. About 134,814 tons³³ of tomatoes were produced in 1977, most of which were industrial tomatoes - some 118,462 tons.³⁴

*In addition to corn, sweet potato, sorghum, and cassava are used to feed animals; in each year from 1973-1977, no more than 5.8 percent of the yearly corn supply has ever been consumed by humans; see Reference 29.

Among the oilseeds,* peanut is the most important not only in terms of its prevalence in the Dominican diet³⁵ but also because of the income it generates for some small farmers; about 48,000 tons of peanut (in shell) were produced in 1977 representing an increase of 10.2 percent over 1976 but a decline of more than 19 percent from the 1974 figure.³⁶ Peanut oil imports decreased steadily over the period 1973-75 but rose sharply in 1976 and 1977.³⁷

The forestry/fishing sector share in GDP went from 0.6 percent in 1973 to 0.4 percent in 1977.³⁸ Although this is a relatively small decline, it indicates, nevertheless, that the sector has not kept pace with the demands of a rising population. There are two primary reasons for this state of affairs in the forestry/fishing sector. Since the modification of the forestry law (No. 206) in 1967, limiting timber cutting rights in order to prevent further deterioration of forest lands,³⁹ output of timber and wood products has declined as much as 29 percent (1969) and by 1977 was still 3.6 percent less than the 1968 output figures.⁴⁰ The other main reason is that fishing methods as now practiced in the DR are primitive and inefficient; for example, the boat (known as the "yola") used by most fishermen is slow, cannot navigate well in relatively rough waters, and does not have facilities for preserving (ice or brine) either the catch or storing additional fuel supplies. As a result, most fishing activities take place in inshore waters and consequently deplete those areas of formerly common fish varieties.

Although the DR is still in the very early stages of industrialization, the production of manufactured goods has been growing at a healthy rate. The manufacturing sector grew at an average annual rate of 5.3 percent from 1973 to 1977; this compares favorably with the growth rates of the agriculture, forestry/fishing, and livestock sectors but less so with the mining, construction, electric, and transportation sectors.⁴¹ The 1977 production estimates for the chemical industry indicate that of the industry's five main products only two fell below their 1976 output figures; furfural declined from 34,226 tons in 1976 to 30,249 tons in 1977 and output of paints dropped from 6,806 liters to 5,904 liters; on the other hand, chemical fertilizers increased from 176,539 tons to 183,057 tons, urethane foam from $11.60 \times 10^6 \text{ ft}^2$ to $13.24 \times 10^6 \text{ ft}^2$, and soap from 25,841 tons to 28,378 tons.⁴² The two-plant cement industry produced some 862,126 tons of cement in 1977 representing an increase of almost 32 percent from 1976,⁴³ and the value of textiles produced increased from RD \$27.9 million to RD \$29.5 million (1970 prices) during the same period.⁴⁴ Table 4 shows output of selected manufactured products from 1973 to 1977.

Of the wide variety of mineral resources in the DR, nickel is by far the most important; exported as ferronickel since 1974, only sugar, coffee, and cocoa surpassed it as earner of foreign exchange in 1977. Prior to 1972 when the RD \$200 million Falconbridge nickel project** was initiated, about 80

*Coconut (copra), cotton, and soya are the other well-known oil crops.

**The Falconbridge Dominicana Company which is jointly owned by the government and two foreign firms (Canadian, U.S.) was responsible for the RD \$200 million initial financing. To date, this has been the largest single investment project in the DR's history.

TABLE 4

DOMINICAN REPUBLIC

PRODUCTION OF SELECTED MANUFACTURED PRODUCTS, 1973-1977

Year	Furfural (tons)	Paint (liters)	Fertilizer (tons)	Urethane Foam (ft ²)	Soap (tons)	Cement (tons)
1973	26,970	4,964	184,084	4,632	22,810	581,925
1974	24,021	4,640	164,365	5,445	21,848	642,518
1975	35,660	5,165	143,929	6,666	22,862	554,931
1976	34,226	6,806	176,539	11,604	25,841	653,877*
1977*	30,249	5,904	183,057	13,246	28,378	862,126

*Preliminary figures.

Source: Reference 12, pp. 50-51.

percent of all mining activities were confined to the extraction of bauxite and about 20 percent to limestone, gypsum, salt, and building stones. Since the completion of the extracting and processing facility near the town of Banao, however, nickel has replaced bauxite as the primary mining industry. Table 5 shows production of some selected minerals from 1973 to 1977.

1.3 FOREIGN TRADE

Among Caribbean countries, the Dominican Republic is one of the most active in international trade. In 1977, about 66 percent of all its exports (market value) went to the United States, 7 percent to both Portugal and Puerto Rico, 2 percent to both Spain and Morocco, 1.6 percent to both Venezuela and Belgium-Luxembourg and anywhere from .2 to 5 percent each to Italy, Haiti, and Japan.⁴⁵ With the exception of Morocco, all these countries, especially the United States, Venezuela, and Puerto Rico, provided the bulk of the DR's imports for that same year.⁴⁶ In 1975, the DR ranked first as supplier to the United States for sugar, fourth for cocoa, and fifth for bauxite.⁴⁷ Sugar accounted for 28 percent of the value of exports in 1977 (down 7.5 percent from the previous year), followed by coffee with 20.4 percent (down 8 percent from 1976), cocoa with 12 percent (down almost 6 percent), ferronickel with 11.6 percent (a decline of about 3 percent), and gold and silver alloys with 7 percent (up .6 percent during the same period).⁴⁸ The balance of payments figures, however, provide a better view of the performance of the economy as a whole.

For five of the eight years between 1969 and 1977 the DR ran a trade deficit. After the trade deficit had increased from RD \$64 million in 1970 to RD \$69 million in 1971, the following two years (1972 and 1973) saw surpluses of RD \$9.98 million and RD \$20.26 million, respectively; by 1974, the country again experienced a negative trade balance (RD \$36.19 million) but recovered in 1975 with a surplus of RD \$121.16 million. Since then the country has been running a deficit each year, reaching some RD \$66.98 million in 1977 and RD \$184.2 million in 1978.⁴⁹ The overall balance of payments, on the other hand,

TABLE 5

DOMINICAN REPUBLIC

MINERAL PRODUCTION, 1973-1977

Mineral	1973	1974	1975	1976	1977 ^a
Bauxite (tons)	1,085,645	1,195,607	785,094	621,247	574,966
Ferronickel (tons)	28,298	30,942	26,922	24,399	24,899
Gold (tons)	-	-	6	13	11
Silver (tons)	-	-	3	28	42
Gypsum (tons)	266,641	383,892	193,553	207,562	221,572
Sand (m ³)	70,930	94,040	136,548	211,856	200,984
Gravel (m ³)	31,740	37,260	53,824	104,219	151,127
Limestone (tons)	105,970	280,247	252,097	247,642	285,623
Salt (tons)	39,129	39,830	37,424	35,431	48,592

^aPreliminary figures.

Source: Reference 12, p. 47.

has been in surplus each year since 1970,⁵⁰ with the exception of 1976, as Table 6 shows.

The primary reason for these substantial deficits in the balance of trade since 1975 has been the collapse of the world market price for sugar, the country's main export, together with the increased cost of petroleum. For example, the world market (fob Caribbean ports) price of sugar dropped from U.S. \$0.132 per pound in December 1975 to U.S. \$0.0709 per pound in October 1977⁵¹ while the Saudi Arabian (fob Ras Tanura) posted price for crude petroleum jumped from U.S. \$11.53 per barrel in 1975 to U.S. \$13.00 per barrel in June of 1977⁵²; so that, whereas the DR's sugar sales in 1975 brought in about RD \$522 million and its oil purchases cost about RD \$169 million that same year, in 1977 sugar sales brought RD \$218 million and oil purchases cost RD \$189 million.⁵³ The 1979 figures are even more revealing - "sugar sales brought \$225 million and oil purchases cost \$325 million" - according to the DR's Minister of Finance, Bolivar Baez Ortiz.⁵⁴ As of March 1979 international reserves stood at U.S. \$128.2 million⁵⁵ which was equivalent to about one and three quarter months' imports if the January import bill is used as a guide.⁵⁶

In 1977, principal imports and exports in descending order of value were as follows:

Ranking of Imports and ExportsImports

Petroleum (crude, products)
Wheat
Rice
Automobiles (including station
wagons and jeeps)
Peanut oil
Corn
Buses (micro, omni, trolley)

Exports

Sugar
Coffee
Cocoa
Ferronickel
Gold and silver alloys
Tobacco
Bauxite

TABLE 6

DOMINICAN REPUBLIC

BALANCE OF PAYMENTS, 1973-1977
(millions of SDRs^a)

	1973	1974	1975	1976	1977
A. <u>Goods, Services, and Unrequited Transfers</u>	- <u>82.1</u>	- <u>201.1</u>	- <u>61.3</u>	- <u>211.2</u>	- <u>226.3</u>
Merchandise: exports fob	370.9	529.5	736.2	620.5	668.5
Merchandise: imports fob	- 353.9	- 559.6	- 636.4	- 661.4	- 726.0
Trade balance	17.0	- 30.1	99.8	- 40.9	- 57.5
Services: credit	61.9	81.5	99.2	109.5	120.4
Services: debit	- 186.6	- 281.6	- 292.4	- 320.2	- 332.2
Total (goods and services)	- 107.7	- 230.2	- 93.4	- 251.6	- 269.3
Private unrequited transfers	24.1	27.6	29.5	37.8	40.8
Total (excluding government unrequited transfers)	- 83.6	- 202.6	- 63.9	- 213.8	- 228.5
Government unrequited transfers	1.5	1.5	2.6	2.6	2.2
B. <u>Long-Term Capital, excluding Groups D and F</u>	<u>58.3</u>	<u>123.4</u>	<u>131.2</u>	<u>145.9</u>	<u>156.3</u>
Direct investment (in DR)	28.9	44.5	52.6	51.9	39.3
Other private	11.8	9.6	33.6	28.2	44.6
General government	17.6	69.3	45.0	65.8	72.4
Total, A plus B	- <u>23.8</u>	- <u>77.7</u>	<u>69.9</u>	- <u>65.3</u>	- <u>70.0</u>
C. <u>Short-Term Capital, excluding Groups D and F</u>	<u>51.4</u>	<u>80.9</u>	- <u>47.4</u>	<u>52.7</u>	<u>102.4</u>
Deposit money banks	13.2	25.3	- 32.8	- 6.6	20.5
Other private	- 15.9	30.4	21.2	14.6	- 23.2
General government	-	-	- 0.1	-	-
Central monetary institutions	14.2	31.8	- 1.5	- 3.6	- 7.2
Net errors and omissions	39.9	- 6.6	- 34.2	48.3	112.3
Total, A through C	<u>27.6</u>	<u>3.2</u>	<u>22.5</u>	- <u>12.6</u>	<u>32.4</u>

TABLE 6 (continued)

DOMINICAN REPUBLIC

BALANCE OF PAYMENTS, 1973-1977
(millions of SDRs^a)

	1973	1974	1975	1976	1977
D. <u>Exceptional Financing</u> ^b	-	-	-	-	-
Total, A through D	<u>27.6</u>	<u>3.2</u>	<u>22.5</u>	- <u>12.6</u>	<u>32.4</u>
E. <u>Counterpart Items</u>	-	-	-	-	-
Monetization/demonetization of gold	-	-	-	-	-
Allocation of SDRs	-	-	-	-	-
Total, A through EC	<u>27.6</u>	<u>3.2</u>	<u>22.5</u>	- <u>12.6</u>	<u>32.4</u>
F. <u>Reserves and Related Items</u>	- <u>27.6</u>	- <u>3.2</u>	- <u>22.5</u>	<u>12.6</u>	- <u>32.4</u>
Use of IMF credit	- 3.8	-	-	21.5	15.0
Other liabilities	-	-	-	-	-
Monetary gold	- 0.3	- 0.1	0.2	-	- 0.8
SDRs	0.1	- 0.4	0.7	0.5	0.8
Reserve position in IMF	- 10.8	10.8	-	-	-
Foreign exchange and other claims	- 12.8	- 13.5	- 23.4	- 9.4	- 47.4
Conversion rates: RD\$ per SDR	<u>1.1921</u>	<u>1.2026</u>	<u>1.2141</u>	<u>1.1545</u>	<u>1.1675</u>

^aSpecial drawing rights (issued by the IMF from 1970).^bThe components of "exceptional financing" can be any subitem under items: other private, general government, deposit money banks, central monetary institutions in Group B or C.^cOverall balance.Source: International Monetary Fund, Balance of Payments Yearbook, Volume 29, December 1978.

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3. The World Bank estimate for the average annual population growth rate between 1970 and 1976 is 2.9 percent (see World Bank Atlas 1978); and the IMF figure for the same period is also about 2.9 percent (calculated from International Financial Statistics, Vol. XXX, No. 12, December 1977 and Vol. XXXII, No. 5, May 1979).
4. World Bank, World Economic and Social Indicators, Report No. 700/78/02, p. 42, April 1978.
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34. Only about 16,352 tons of salad tomatoes were produced in 1977; see Plan Operativo 1978, Anexo 1, Table 14.
35. Annual per capita consumption of peanut oil in the DR is about 20 pounds; see Diagnostico Y Estrategia Del Desarrollo Agropecuario 1976-1986, Secretaría Del Estado de Agricultura, p. 197.
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2. ENERGY RESOURCES AND PRODUCTION

2.1 COMMERCIAL ENERGY

2.1.1 Oil

Although oil-bearing formations are known to exist in the southwestern portion of the Dominican Republic, no commercially significant deposits have been identified. The exploration efforts have been sporadic, however, and a more comprehensive evaluation of the oil resources is planned. As of 1976, only eight potential oil-bearing structures had been drilled, one of which (Maleno in the Azua province) produced small amounts of oil.¹ The existence of valuable oil resources cannot be ruled out, although it appears unlikely that domestic oil will displace significant quantities of imported oil, at least in the near future.

In the absence of any domestic production, the Dominican Republic has had to rely on imports to satisfy all of its oil requirements. The value of imports of petroleum and petroleum products for the 1967 to 1977 period is given in Table 7. The sixfold increase between 1971 and 1974 is the result of increases in both the petroleum prices and, as illustrated in Table 8, the quantities imported.

The composition of the petroleum imports changed significantly with the installation of an oil refinery in the port of Haina near Santo Domingo. The refinery, owned jointly by the Dominican government and Shell, had its first full year of operation in 1973. Reconstituted crude oil, consisting of approximately 60 percent crude and 40 percent semifinished products, is imported from Venezuela to supply both the refinery and some electricity generation in the industrial sector. The refinery capacity is approximately 11 million barrels² (67×10^{15} joules) a year and its historical outputs are given in Table 9. With the exception of fuel oil, the refinery production has displaced most of the petroleum product imports.

TABLE 7
IMPORTS OF PETROLEUM AND PETROLEUM DERIVATIVES³
(Millions of RD \$)

Year	Refined Fuel Products	Nonfuel Petroleum Derivatives	Reconstituted Crude	Total
67	11.2	1.8	---	13.0
70	16.2	2.8	---	19.1
71	22.0	3.5	---	25.4
72	19.3	11.0	7.8	38.1
73	14.6	10.7	29.4	54.7
74	26.1	12.1	118.5	156.8
75	20.0	13.5	143.8	177.2
76	14.3	22.9	146.6	183.8
77	18.6	11.1	158.0	187.8

Source: Reference 2.

TABLE 8
IMPORTS OF PETROLEUM AND PETROLEUM DERIVATIVES
(10¹⁵ joules)

Year	Gasoline	Aviation Gasoline	Fuel Oil	Gas Oil	Kerosine	LPG	Reconstituted Crude	Total Fuel	Non- Fuel	Total
67	8.0	0.3	8.2	4.4	1.7	0.4	---	23.0	1.5	24.5
70	9.0	0.6	13.9	6.2	3.5	1.1	---	34.3	5.1	39.4
71	11.1	0.6	5.7	10.2	2.9	1.2	---	31.7	2.8	34.5
72	11.5	0.6	12.6	6.4	1.4	---	17.8	50.3	17.9	68.2
73	2.0	1.2	4.9	1.8	0.2	---	54.5	74.6	25.9	100.5
74	---	2.1	12.6	1.9	---	---	54.8	81.4	6.8	88.2
75	---	1.5	6.0	1.6	---	N.A.	73.8	82.9	1.5	84.4
76	---	0.1	8.1	0.2	---	N.A.	74.5	82.9	3.0	85.9
77	---	0.2	10.0	0.5	---	---	73.8	84.5	3.1	87.6

Source: Reference 2 and energy coefficients from Appendix D.

TABLE 9
REFINERY OUTPUTS, 1973-77
(10¹⁵ joules)

Year	Gasoline	Fuel Oil	Gas Oil	Kerosine	LPG	Total
73	11.7	10.5	6.8	2.3	1.5	32.1
74	12.7	10.2	12.3	2.3	2.0	39.5
75	14.7	15.7	15.0	2.3	2.2	50.9
76	15.1	17.8	15.9	2.2	2.4	53.4
77	15.1	17.5	16.4	2.1	2.6	53.7

Source: Reference 4.

2.1.2 Coal and Peat

Peat and lignite deposits have been identified in the Bajo Yuna area and on the Samana peninsula, but the magnitude and quality of these reserves have not been quantified.⁵ It is, therefore, impossible to determine whether the deposits will warrant exploitation. With no domestic coal production to date, the Dominican Republic has had to import small quantities of coal. On the basis of industrial consumption statistics⁶ it would appear that coal imports were less than 200 tons in 1977.

2.1.3 Hydropower

The theoretical hydroelectric generation potential in the Dominican Republic has been estimated at 50,000 x 10⁶ kWh (180 x 10¹⁵ joules) per annum, of which between 10 and 40 percent could technically be developed.⁷ In the absence of comprehensive hydrographic data, however, such estimates are necessarily very uncertain and it may mean more to consider only the hydropotential from sites which have already been evaluated. As of 1976, fifty sites⁸ had been identified with a total capacity of approximately 1 GW_e and an electricity generation capability of 2,500 GWh per annum. A small number of minihydro sites (less than 5000 kW_e) had also been identified.

In the past the development of the hydroelectric resources has been hindered by the high capital costs, the relatively long lag time, and the existence of competing water requirements (principally irrigation). With the current oil prices, however, the development of hydro sites has become more cost-effective.

The historical development of hydro capacity is given in Table 10. Only 13 percent of the total capacity of identified sites have been developed. In addition, the Taveras and Valdesia plants have been operating sporadically and in early 1977 they were achieving only 20 to 40 MW_e compared to a nominal capacity of 136 MW_e. This was largely the result of water releases for irri-

gation which have prevented the reservoirs from filling and accounts for the relatively low electricity generation figures given in Table 11.

2.1.4 Solar and Wind

The information on the solar resources of the Dominican Republic is limited to radiation data from four sites, sunshine hour data from seven sites and cloud cover estimates from a total of 24 sites.¹⁰ Acosta,¹¹ basing his calculations on the correlation between cloud cover and solar radiation, estimates an annual average radiation of 2000 joules per cm² for the 24 stations measuring cloud cover. On a monthly basis the average radiation estimate varies from 1800 joules per cm² for January to 2300 for July.

Although the existing estimates show relatively high levels of solar radiations, this fuel source is virtually untapped at present. One company, Energia Solare S.A., has been manufacturing solar water heaters but has sold only 300 units in the last three years.

Data on the wind energy resources of the Dominican Republic appear to be even more limited, perhaps because the information that does exist is not promising. The average wind speed at the meteorological sites has been estimated at about 4 m/s (which is well below the optimal wind speed for most commercial windmills). Tabor¹² estimates that there are probably 500 or more very small windmills used in remote areas without electricity but that they are being replaced by electricity and gasoline pumps.

TABLE 10

HYDRO CAPACITY EXPANSION

Date of Installation	Location	Nominal Capacity (kW _e)
1949	Constanza	250
1959	Jimeno	7500
1966	Las Damas	7500
1973	Taveras I	40000
1973	Taveras II	40000
1975	Valdesia	27000
1975	Valdesia	27000
<u>Total Capacity</u>		149250

Source: Reference 9.

TABLE 11
HYDROELECTRIC GENERATION 1967-75
(GWh)

Year	Jimenon	Las Damas	Constanza	Tavera	Valdesia	Total
67	36.7	9.7	0.7			47.1
70	57.0	24.3				81.3
71	39.8	26.3	1.1			67.2
72	48.1	22.4	1.2			71.7
73	39.5	18.4	1.3	123.8		183.0
74	40.4	17.0	1.2	120.1		178.7
75	34.4	18.1	1.5	92.6	15.3	161.9
76						
77						

Source: Marcelo Jorge Perez, Características generales de la demanda y la oferta de energía, in CODIA 50, 1976.

2.1.5 Geothermal

There are a number of indications that the Dominican Republic may have significant geothermal resources. Geographically, the country lies in a tectonically active region, a prerequisite for the existence of high temperature geothermal resources. Past lava emissions and volcanic activity have been identified in geological studies and thermal springs exist along one of the island's faults. In addition, a chemical analysis¹³ of the two major thermal springs (Yayas and Maguella in the Azua Province) showed a similar chemical composition to spring waters in currently exploited geothermal sites. It is possible, however, that the geothermal resources are limited to low grade heat with limited applications, and further exploration (including drillings) is required to determine the extent and quality of this resource.

2.2 NONCOMMERCIAL ENERGY

2.2.1 Forest Resources

According to a forest inventory for the Dominican Republic¹⁴ published in 1973, there are about one million hectares of forest in the Dominican Republic accounting for approximately 22 percent of its surface area. The forests are located principally in the southwest and in the east along the coast. Of the forested area, only 34 percent was found in its natural state, the remainder having been partially depleted by logging (38 percent), charcoal production (17 percent), or forest fires, grazing, and nomadic agriculture (11 percent). The previously high rate of deforestation has decreased significantly, however, since most of the forests are now located in areas with poor growing conditions, and logging has been under strict government control since 1967.

The energy potential of the forested area depends on the forest management techniques, the quantity of wood destined to nonenergy uses, and the quantity of wood which is not economically exploitable (e.g., inaccessible).

If all of the forested area was in its natural state and could be exploited for fuel purposes, the total sustainable yield of roundwood would be roughly 38×10^{15} joules per annum (see Table 12). Excluding 200,000 hectares which are considered inaccessible, the figure falls to approximately 30×10^{15} joules. As noted above, however, most of the accessible forest land has been partially depleted and these estimates are upper limits to the potential roundwood production of the forested areas; currently sustainable yields could be as little as half of these estimates and a significant portion is likely to go to nonfuel uses.

In addition to the wood resources on forested areas noted above, wood can be collected from the trees located outside of forests and from tree stumps and branches not included in the forest inventory. Reforestation projects and tree farms could also add significantly to the wood reserves. However, in the absence of adequate data, we will not attempt to assess these resources.

Estimates of the actual production of fuelwood and charcoal are given in Tables 13 and 14. The discrepancies between the two estimates are insignificant given the level of uncertainty in the efficiency of charcoal production. Calculations based on a national household survey,* however, yield an estimate of 5.7×10^{15} joules for charcoal in 1977, well above the charcoal production estimate given in Table 13. In any case, it is evident that wood production is high relative to the resource base and, if indiscriminate cutting continues, the remaining forests will be rapidly depleted.

2.2.2 Agricultural Residues

Approximately 20 percent of the Dominican Republic's land area, which amounts to about one million hectares, is under agricultural cultivation. Table 15 shows the production of most of the major crops and rough estimates

TABLE 12
SUSTAINABLE YIELD OF FORESTED AREA
(Under Average Conditions)

Forest Type	Area ^a (10^3 ha)	Net Primary ^b Production ($J \times 10^9$ /ha)	Total Annual Production ($J \times 10^{15}$)
Pine/Mixed	335,000	42	14
Dry	400,000	14	6
Moist Deciduous	<u>250,000</u>	70	<u>18</u>
	985,000		38

Source: ^aReference 14.

^bD. E. Earl, Forest Energy and Economic Development, Oxford University Press, 1975.

*An unpublished survey by the Central Bank's Department of Economic Studies.

of the agriculture residues produced with their energy content. Sugarcane alone accounts for at least 70 percent of the energy content of these agricultural residues and is currently the only one used extensively as a fuel (although small amounts of peanut residue consumption are also recorded). Sugarcane residue, or bagasse, is used principally as a fuel for electricity generation for sugar processing. In addition, Central Romana, a subsidiary company of Gulf and Western which mills approximately 3 million tons of sugarcane a year, uses the bagasse as a feedstock in the production of approximately

TABLE 13
WOOD PRODUCTION (FAO), 1967-77

Year	Industrial Roundwood		Firewood & Charcoal ^a		Total	
	10 ³ m ³	J x 10 ¹⁵	10 ³ m ³	J x 10 ¹⁵	10 ³ m ³	J x 10 ¹⁵
67	2	--	1800	18.9	1802	18.9
70	1	--	1840	19.3	1841	19.3
71	18	0.2	1840	19.3	1858	19.5
72	29	0.3	1840	19.3	1869	19.6
73	34	0.4	1840	19.3	1874	19.7
74	29	0.3	1850	19.4	1879	19.7
75	13	0.1	1785	18.7	1798	18.8
76	14	0.1	1737	18.2	1751	18.3
77	14	0.1	1737	18.2	1751	18.3

Source: Reference 15.

^aCharcoal has been converted into wood equivalent.

TABLE 14
WOOD AND CHARCOAL RESOURCE USE, 1973-77
(10¹⁵ joules)

Year	Wood	Charcoal	Total Wood Equivalent ^a
73	13.5	1.4	15.8
74	14.0	1.4	16.3
75	14.1	1.5	16.6
76	14.2	1.6	16.9
77	14.4	1.6	17.1

Source: Reference 16.

^aAssuming a 40 percent energy loss in converting wood to charcoal.

TABLE 15
CROP RESIDUES, 1977

Crop	Production (metric tons) 10 ³	Residue Coeff.	Residue Production	
			MT 10 ³	J x 10 ¹⁵
Sugarcane	11,140	0.35	3899	27-43
Rice	289	1.5	434	5.6
Corn	54	1.0	54	0.7
Peanuts	48	1.0	48	0.6
Cassava	162	1.0	162	2.1
Plantains	600	0.15	90	1.1
Cotton	4	1.0	4	0.1
Potato & Sweet potato	71	0.15	11	0.1
<u>Total</u>				37.2-53.2

Sources: Production: Reference 18.
 Residue Coefficients: Reference 19.
 Energy value coefficients: Reference 19 (and Reference 20 for Sugar cane). Range for Sugarcane represents the difference between the assumed energy content for bagasse of the two sources (presumably due to differences in the moisture content assumed).

39,000 tons of furfural a year. The furfural residue also has a high energy content, and apparently very little of the energy content of the bagasse is lost in this process.¹⁷ Molasses, another sugarcane residue, is consumed domestically by the feed and alcohol (primarily rum) industries, or exported.

The use of residues from crops other than sugar is constrained by the difficulties involved in collection. Thus it is not realistic to assume that this resource could be utilized fully for energy conversion.

2.2.3 Animal Waste

Of the animals listed in Table 16, only cattle produce large quantities of animal waste. Poultry might also produce significant quantities but we could not obtain data adequate to provide an estimation. Apparently, animal waste is not currently used as a fuel and, as in the case of crop residues, collection problems are likely to prevent it from ever being used in full.

TABLE 16
ANIMAL RESIDUES 1971

Animal	Head (000) ^a	Residue Coeff. ^b	Residue Production	
			metric tons(000)	J x 10 ¹⁵
Cattle	1712	1.7	2,900	42
Pigs	876	0.11	96	1
Sheep	26	0.11	3	--
Goats	283	0.11	31	--
Horses	217	1.5	326	5
Mules	98	0.11	11	--
Asses	115	0.11	13	--
			<u>Total</u>	48

Sources: ^aReference 18.
^bReference 19.

ENERGY RESOURCES AND PRODUCTION

NOTES AND REFERENCES

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3. Note: Slight inconsistencies existed in the original table (in Reference 2), and crude imports by Gulf and Western may not be accounted for.
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16. Roberto Liz et al., op. cit.
17. T. V. Long, op. cit.
18. Oficina Nacional de Estadistica, Republica Dominicana en Cifras, 1978.
19. U.S. Department of Energy, Joint Peru/United States Report of Peru/United States Cooperative Energy Assessment, Annex 8, August 1979.

3. ENERGY CONSUMPTION PATTERNS

3.1 TRENDS AND CHARACTERISTICS

Total energy resource consumption in the Dominican Republic increased from approximately 74 quadrillion joules in 1970 to 129 quadrillion joules in 1977, with an annual average growth rate of about 8 percent. Over the same period, per capita energy consumption rose from 18.5 billion (10⁹) joules to 25.9 billion joules.

As illustrated in Table 17, most of this growth was in the consumption of oil-based fuels which accounted for almost two thirds of energy consumption in 1977 compared to less than half in 1970. The striking increases in oil consumption between 1971 and 1973 correspond to a period of high economic growth (GDP at constant market prices grew at over 11 percent a year¹) and to the opening of the Haina oil refinery. Subsequently, after the OPEC price increases and the fall in the sugar prices in 1976, the growth in oil consumption declined and between 1974 and 1977 it averaged less than 2 percent. Of the estimated 64 quadrillion joules of oil consumed in 1977, fuel oil accounted for 34 percent, gas oil 20 percent, crude 21 percent, gasoline 18 percent, and kerosine and LPG 3 percent each.

Hydro resources still accounted for only 2.2 percent of energy resource consumption in 1977 in spite of a comparatively high annual growth rate of 16 percent. As noted in Section 2, competing water requirements for irrigation have prevented the existing hydro capacity from being used effectively. In the absence of such difficulties the hydroelectric generation could have been far greater than the actual figures.

Wood consumption (including charcoal) fell slightly and accounted for only 14 percent of energy consumption in 1977, down from 26 percent in 1970. This decrease is probably brought on by rural to urban migration and rising household income causing households to substitute oil based fuels for part of their wood consumption. It should be noted, however, that these figures do not imply that the wood consumption is having a smaller effect on the forest resources. The level of wood consumption has been decreasing very slowly (if at all), and if more wood is being purchased on the commercial market (as is likely to be the case since urban households cannot collect wood locally) the roundwood consumption may actually have grown significantly. While rural households tend to obtain a large proportion of their wood from branches and twigs, whose collection does not harm the forests significantly, the commercial wood is likely to be roundwood and charcoal obtained from felling.

Bagasse consumption, which is intimately linked with sugarcane production, grew at an annual rate of 4 percent. There is a possibility, however, that a significant portion of the bagasse reported here (which is approximately equal to production) was not used as fuel. There are discrepancies between the bagasse consumption estimates and some bagasse is used as animal feed and in producing furfural.

In addition to the energy consumption recorded in Table 17, small amounts of other crop residues, solar and wind energy, and coal are used. These energy sources do not make up a significant portion of total energy consumption, however.

TABLE 17
ENERGY CONSUMPTION, 1970-77
(joules x 10¹⁵)

Year	Oil fuels ^a		Hydro ^b		Wood + Charcoal ^c		Bagasse ^d		Total
	10 ¹⁵ J	%	10 ¹⁵ J	%	10 ¹⁵ J	%	10 ¹⁵ J	%	10 ¹⁵ J
70	34.3	46	1.0	1	19.3	26	19.6	26	74.2
71	31.7	42	0.8	1	19.3	26	23.1	31	74.9
72	47.1	53	0.9	1	19.3	22	22.4	25	89.7
73	70.0	61	2.2	2	19.3	17	23.2	20	114.7
74	77.7	63	2.1	2	19.4	16	23.3	19	122.5
75	77.1	65	1.9	2	18.7	16	21.5	18	119.2
76	78.7	63	3.6	3	18.2	15	25.2	20	125.7
77	82.4	64	2.8	2	18.2	14	25.6	20	129.0

Sources:

^aRefinery sales from Long.² Petroleum product imports from Section III, Table 8 this report. Refinery losses are not included.

^b1970-75 from Section III, Table 11 (converted to fossil fuel equivalent assuming 30% efficiency). 1976-77 from Roberto Liz et al.³

^cFAO estimates of wood production⁴ converted to energy assuming 14 x 10⁹ joules/ton.

^d1970-72 from World Bank estimates of Bagasse production¹ converted to energy assuming 7 x 10⁹ joules/ton. 1973-77 from Robert Liz et al.³

3.2 SECTORAL CONSUMPTION

The energy use in the Dominican Republic by major consuming sector is summarized in Table 18. The industrial sector appears to be the largest energy consumer, accounting for 38 percent of the oil, 61 percent of the biomass energy consumption, and 38 percent of the electricity sold by the public utility. An additional 19 percent of total resource consumption is lost in the generation and transmission of the public sector electricity. Transportation, which depends totally on oil-based fuels, accounts for about 22 percent of the oil consumption but only 15 percent of total energy use. The residential sector is the next largest total energy consumer, but 66 percent of the residential energy is from wood (either directly or in the form of charcoal) which is used inefficiently: the amount of useful energy required by the residential sector is comparatively small.

3.2.1 Industry

In 1977, the industrial sector consumed approximately 60 quadrillion joules of fuel (including electrical energy). Estimates of fuel consumption by industrial category for 1975 are given in Table 19. Most of the bagasse and crude oil and part of the fuel oil and gas oil consumption are apparently used for captive electricity generation (electricity generated by the industries themselves), and approximately 57 percent of the electricity consumption

TABLE 18

ENERGY CONSUMPTION BY SECTOR AND RESOURCE, 1977
(10¹⁵ joules)

	Gasoline	Aviation Fuel	Fuel Oil	Gas Oil	Kerosene	LPG	Crude	Total Oil	Hydro	Electricity Purchases	Noncommercial			TOTAL
											Bagasse	Wood	Charcoal	
Industry ^a	0.7	--	8.6	5.5	--	0.1	16.4	31.3	--	2.1	25.6	1.0	--	60.0
Transportation ^b	14.3	0.2	--	4.0	--	--	--	18.5	--	--	--	--	--	18.5
Residential ^c	--	--	--	--	2.3	2.5	--	4.8	--	2.1	--	7.7	5.7	20.3
Public Utility ^d	--	--	19.5	5.6	--	--	1.1 ^f	26.5	2.8	(-5.6)	--	--	--	23.4
Other ^e	--	--	--	1.6	--	--	--	1.6	--	1.4	--	--	--	3.0
Total Consumption	15.0	0.2	28.1	16.7	2.3	2.6	17.5	82.7	2.8	--	25.6	8.7	5.7	125.2

Sources and Notes:

^aOil (except fuel oil and crude) and wood from industrial consumption statistics⁵ with the electric sector and petroleum refining subtracted out on the basis of 1975 coefficients.⁵ Bagasse from Table 17 of this report. Electricity from Long.²

^bTotal consumption from Reference 7 quoted in Long.² Transportation assumed to consume all remaining gasoline, additional consumption assumed to be gas oil.

^cFrom fuel mix tables (Section).

^dFuel oil and gas oil from INDOTEC. Hydro from Table 17 of this report (fossil fuel equiv.).

^eGas oil is leftover. Electricity from Long.²

^fApproximately 1.1 x 10¹⁵ joules of oil are used by Falconbridge (the ferronickel enterprise) in the generation of electricity sold to the public utility.

(2.7×10^{15} joules) appears to be from this source. Unfortunately, since captive generation and purchase of electricity from the public utilities are not separated in the industrial consumption statistics, total energy use by industrial category cannot be estimated accurately. In addition there are a number of inconsistencies between the estimates in Table 19 and figures reported elsewhere (see notes to table). Nonetheless some tentative generalities can be made.

TABLE 19
INDUSTRIAL ENERGY CONSUMPTION, 1975
(joules $\times 10^{12}$)

Division	Fuel Oil	Gas Oil	Crude	Other	Subtotal	Wood and Charcoal	Bagasse	Electricity
Mining	595	1,146	19,284	18	21,043	-	-	12,360
Sugar	-	3,668	363	95	4,126	1,425	1,632	900
Other Foods	624	332	-	19	975	723	-	744
Beverages & Tobacco	267	57	-	12	336	-	-	168
Textiles, Wearing Apparel & Leather	89	51	-	3	143	6	-	148
Wood & Paper Products	334	3	-	2	339	-	-	380
Chemical Rubber & Plastic Products	2,850	90	-	7	2,947	-	-	344
Nonmetallic Mineral Products	3,737	92	-	47	3,876	10	-	739
Basic Metals Metal Products	118	70	-	-	188	-	-	155
Services	2	46	-	-	48	-	-	115
	-	17	-	2	19	-	-	20
TOTAL	8,616	5,572	19,647	205	34,040	2,164	1,632	16,073

Source: Reference 5.

Note: Does not include electricity or petroleum industries (which were inconsistent with estimates in Reference 2). Electricity consumption (valued here at fossil fuel equivalent) appears to include captive generation and therefore fuel uses cannot be totaled. Bagasse consumption quoted here is less than one tenth of that quoted in Reference 2. The reason for this discrepancy is unknown.

The four largest industrial energy consuming categories [mining, food processing (including sugar), chemical, and nonmetallic mineral products] appear to account for almost 97 percent of industrial oil consumption and virtually all of the industrial consumption of the biomass fuels. Within the mining sector, most of the energy is consumed by the Falconbridge nickel enterprise which uses all of the crude oil allocated to the mining sector in Table 19. Estimates of the Falconbridge energy consumption in 1977 are shown in Table 20. The soft market for nickel combined with rising oil prices has led to production cutbacks, and Falconbridge is currently selling some of its excess electricity to the public utility, CDE. Since nickel is one of the Dominican Republic's major exports, its dependence on oil is of particular concern.

Sugar processing, the next largest industrial energy consuming category, accounted for 12 percent of the industrial oil consumption and almost all of the biomass consumption in 1975. [It should be noted that the bagasse consumption given in Table 19 is less than 10 percent of the consumption reported in Long² for the Consejo Estatal de Azucar (C.E.A.), the government's sugar processing enterprise]. The manufacturing of nonmetallic mineral products, whose energy consumption is dominated by the cement industry, accounted for approximately 9 percent of industrial oil consumption followed by the chemical industries with an additional 9 percent.

TABLE 20

PRODUCTION AND ENERGY CONSUMPTION
DATA FOR FALCONBRIDGE (1977)

Input Dry Ore (metric tonnes)	2.28 x 10 ⁶
Production (metric tonnes of nickel)	24,898
Diesel Oil Liters	8.886 x 10 ⁶
Energy (GJ)	358,996
Bunker C Liters	230 x 10 ⁶
Energy (GJ)	9,618,307
Electricity sold to CDE (GJ)	- 3,456
Total Energy Consumption (GJ)	9,973,847
Specific Energy Consumption	or 400.5 GJ/tonne nickel
	160.2 GJ/tonne product

Source: T.V. Long.²

3.2.2 Transportation

A recent study of transportation in the Dominican Republic¹ by Delcanda International Ltd. estimated that approximately 18×10^{15} joules of petroleum products were consumed by the transportation sector in 1977. (This estimate does not include sea, air, or rail, however, for which very little information appears to be available.) As illustrated in Table 21, approximately 26 percent of this total was consumed by private cars, 25 percent by taxis, 13 percent by motorcycles, 2 percent by buses, and 34 percent by trucks (including jeeps). The division between passenger and freight transportation is not clear since the trucks, which are mostly small, carry passengers as well as goods and there is no direct information on freight movement. It would appear however, that at least two thirds of the fuel was used for passenger transportation.

The vehicle fleet has been growing at over 10 percent a year since 1972 (see Table 22) in spite of the oil price increases and high automobile import taxes. By 1977 there were approximately 37 vehicles for every 1000 people compared to 26 in 1972. A detailed breakdown of the types of vehicles operating in 1977 is given in Table 23. Private automobiles are shown to be the most numerous vehicle with approximately one for every 15 families. A disproportionate number of these vehicles operate in Santo Domingo where about three quarters of the private cars are registered and the majority of taxis are located.

The efficiencies of the various transportation modes have not been estimated accurately, which makes it difficult to analyze the transportation sector in detail. There is some concern that the publicos (fixed route taxis) are operating inefficiently. An odd-even system (allowing only half of the fleet to operate on any given day) was developed in Santo Domingo in order to ensure high passenger loads and to prevent the publicos from causing congestion and inefficiency in the alternative transportation modes. Suggestions have also been made to shift the publicos, which are now small cars, over to minibuses or to attempt to shift the ridership to buses,¹⁰ but the information necessary to evaluate the energy impact with such shifts is lacking. Long¹¹ uses two procedures to estimate the efficiency of the publicos. The first procedure, based on hypothetical budget figures, yields an estimate of 63 to 75 passenger kilometers per gallon while the second, using an assumed vehicle efficiency of 20 to 25 kilometers per gallon and a load factor of 4.6 (taken from a passenger occupancy study), estimates an efficiency of 92 to 115 passenger kilometers per gallon. The uncertainty implied by the 50 percent variation between these estimates combined with even greater uncertainty concerning the effects of the publicos on the efficiencies of the other transportation modes makes it virtually impossible to draw any definitive conclusions regarding the energy savings of shifts away from the use of publicos.

Another area in which information appears to be lacking is air, ship, and train transportation. Although only 0.2×10^{15} joules of aviation fuel were imported in 1977 (apparently most of the planes fuel elsewhere), it is possible that significant quantities of reported kerosine/avtur use are destined to airplanes. The rail system transported roughly ten million tons of freight (mostly sugarcane) in 1976 which, given the relatively small travel distances in the Dominican Republic, is unlikely to have consumed a significant quantity of fuel. The DELCANDA study estimated that the railways could be expanded along selected routes to attract an average of 20 percent of the loads cur-

rently being carried by truck. Since rail transport tends to be more energy efficient than truck transport, the recent oil price increases have made such extensions more economically attractive and rail transport could become a significant transportation mode in the future.

Within the international shipping sector approximately 3.5 million metric tons of merchandise were unloaded into the Dominican Republic and 2.5 million on loaded (with less than one percent in both cases by Dominican ships). Coastal shipping is almost insignificant with approximately 135,000 tons shipped in 1976. As in the case of railways, this could become a more important mode of transport in the future.

TABLE 21

GROUND TRANSPORTATION FUEL CONSUMPTION BY VEHICLE TYPE

Vehicle Type	Joules x 10 ¹⁵	Percentage
Private Automobile	4.8	26
Collective Taxis	4.6	25
Jeeps	0.5	3
Small Trucks	3.5	19
Trucks	2.2	12
Buses	0.4	2
Motorcycles	2.4	13
Total	18.3	100

Source: Reference 7 quoted in Long.²

Note: Aviation fuel accounts for an additional 2 x 10¹⁵ joules.

TABLE 22

NUMBER OF REGISTERED MOTOR VEHICLES

Vehicle Type	72	73	74	75	76	77	Average Growth Rate (%/annum)
Automobile	48,736	54,657	62,687	69,687	74,563	80,800	10.6
Trucks	22,117	25,496	29,397	29,678	33,680	36,500	10.5
Buses	1,332	1,485	1,587	1,633	2,010	2,500	13.4
Other	41,215	47,755	49,006	54,693	59,864	65,000	9.5
	113,400	129,393	142,677	155,691	170,117	184,800	10.3

Source: Reference 2.

TABLE 23

OPERATING MOTOR VEHICLES (1977)

Vehicle Type	Number
Private Cars	56,715
Taxis (Intraurban)	18,563
Taxis (Interurban)	7,403
Dump Trucks	2,760
Flatbed and Small Trucks	34,609
Small Farm Trucks	1,010
Jeeps	2,280
Motorized Small Wagons	1,085
Motorcycles	20,991
Heavy Equipment	2,151
Buses (Interurban)	731
Buses (Intraurban)	801
Buses (Private)	779

Source: Association Dominicana de Choferes Unidos; information obtained from the Ministrada por Rentas Internas, through Long.²

3.2.3 Residential

The use of fuels for domestic purposes is dominated by cooking and lighting requirements. The fuels used are primarily LPG, electricity, and charcoal in urban areas and wood and charcoal in rural areas (with small amounts of kerosine used in both areas). The residential fuel use figures quoted here are based largely on a national household expenditure survey carried out in 1976-77. Because of uncertainties in the fuel prices and in the proportion of wood and electricity purchased commercially, the resulting estimates are tentative. A household energy use survey being carried out by PCI should allow more definitive estimates to be derived.

The total fuel consumption of the residential sector is estimated at 20.3 quadrillion joules of which approximately 38 percent is wood, 28 percent is charcoal, 12 percent is LPG, 11 percent is kerosine and 10 percent is electricity. The use of fuels for cooking in urban and rural areas is summarized in Table 24 (with an explanation of terms in Appendix B). As illustrated in this table, while wood and charcoal account for approximately 78 percent of the total fuel use (D), the relatively low efficiencies (e_j) of wood and charcoal devices imply that they satisfy only 61 percent (f_j) of the cooking requirements. The differences in the fuel shares between urban and rural households are striking. In the rural areas wood supplies about one half the cooking requirements, charcoal 28 percent, kerosene 17 percent, and LPG the remainder. In the urban areas the situation is reversed with LPG being the most important (60 percent) and wood and kerosene being almost insignificant.

The household lighting fuel estimates are shown in Table 25. It was assumed that all households which did not purchase electricity from the public utility used kerosine for lighting. Using a "reasonable" value for lighting

energy requirements this procedure accounts for all kerosine sales not allocated to cooking. It is likely, however, that a significant number of households receive electricity without charge (either in company housing or by tapping the electric lines) or use other fuels for lighting. Public utility electricity consumption (besides lighting) is shown in Table 26. Approximately 1.8 quadrillion joules of electricity are consumed by electric appliances. Among the upper income groups a large portion of this electricity probably goes to water heating and air conditioning and possibly some electric cooking.

TABLE 24

TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Cooking, 1977

	Urban			Rural			Total		
Fuel	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
LPG	0.60	0.6	2.2	0.06	0.6	0.3	0.29	0.6	2.5
Kerosene	--	--	--	0.17	0.4	1.3	0.10	0.4	1.3
Charcoal	0.38	0.3	2.8	0.28	0.3	2.9	0.32	0.3	5.7
Wood	0.02	0.2	0.2	0.49	0.2	7.5	0.29	0.2	7.7
Total Fuel Demand ($10^{15}J$)			5.2			12.0			17.2
Basis (10^3 Hshlds)	354.4			494.0			848.4		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10^9J)	6.2			6.2			6.2		

Notes: See Tables 34 and 35.

TABLE 25
TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Lighting, 1977

Fuel	Urban			Rural			Total		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
Electricity	0.68	1	0.11	0.08	1	.02	0.34	1	0.13
Kerosene	0.32	0.25	0.2	0.92	0.25	0.0	0.66	0.25	1.0
Total Fuel Demand ($10^{15}J$)			0.31			0.82			1.13
Basis (10^3 Hshlds)	354.4			494.0			848.4		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10^9J)	0.44			0.44			0.44		

Notes: See Tables 36 and 37.

TABLE 26
TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Appliances, 1977

Fuel	Urban			Rural			Total		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
Electricity	0.68	1.0	1.69	0.08	1.0	0.28	0.33	1.0	1.97
Total Fuel Demand ($10^{15}J$)			1.69			0.28			1.97
Basis (10^3 Hshlds)	354.4			494.0			848.4		
Saturation	0.68			0.08			0.33		
Unit Basic Demand: (10^9J)	7.0			7.0			7.0		

Notes: See Tables 38 and 39.

3.2.4 The Electric Sector¹³

In 1977 the nominal capacity of the Corporacion Dominicana de Electricidad (the public utility) system was 638 MW_e. Table 27 shows the breakdown by type of plant. Approximately 506 MW_e of this total was effective capacity with 263 MW_e in base load plants. For the same year, the gross energy inputs to the CDE system were approximately 5.1×10^{15} joules of oil-based fuels and 2.8×10^{15} joules of hydro (in fossil fuel equivalent), accounting for about 2000 GWh (7.3×10^{15} joules) of on-line electricity generation. In addition, about 1.1×10^{15} joules of oil-based fuels and a small amount of bagasse were used in the industrial sector to generate approximately 84 GWh (0.3×10^{15} joules) sold to CDE. With total CDE electricity sales of slightly more than 1.5×10^9 GWh (5.5×10^{15} joules), implying transmission and distribution losses of 27 percent, the net energy consumption of the electric sector (defined to include all electricity sold by CDE) was about 23.4×10^{15} joules. Historical electricity generation and sales data are given in Table 28.

In the past few years the CDE has encountered a number of problems which have led to an inefficient use of the existing energy resources and an inability to supply the (connected) load. Hydroelectric generation has been beset by problems arising from competing water requirements and the lack of an adequate procedure for allocating the existing water resources between irrigation and hydroelectric generation. Installation delays and the breakdown of existing facilities exacerbated the supply shortages in the system, already short of base load capacity. In addition, the transmission and distribution losses have been increasing (see Table 28) and are far in excess of what could be considered normal. While part of these losses are attributed to theft, which has apparently been increasing rapidly with the increasing electricity prices, the transmission and distribution system is reportedly in poor condi-

TABLE 27
CDE NOMINAL CAPACITY 1977
(MW_e)

Plant Type	Capacity (MW _e)	Share (%)
Steam	336.3	53
Diesel	23.4	4
Hydro ^a	149.5	23
Gas Turbine	98.6	15
TOTAL	637.8	100

Source: References 2 and 3.

Note: ^aIncludes the Tavera and Valdesia facilities from which the CDE "purchases" electricity.

TABLE 28

CDE ELECTRICITY GENERATION (ON LINE), PURCHASES, AND SALES
(GWh)

Plant Type	70	71	72	73	74	75	76	77
Steam	773.9	920.0	1046.2	1115.4	969.9	890.3	1003.1	1514.1
Diesel	8.0	5.6	13.8	22.2	20.4	30.0	17.0	8.7
Gas Turbine	--	--	--	--	267.7	461.6	295.4	280.0
CDE Hydro	82.0	67.0	71.5	59.1	68.2 ^a	53.5	76.7	59.8
Purchased Hydro	--	--	--	123.3	119.7	106.6	(224) ^b	(171) ^b
Other Purchases	8.6	8.1	6.9	6.0	1.6	2.4	31.3	83.9
Total Generation	871.5	1000.9	1138.4	1326.0	1447.5	1544.4	1647.5	2117.5
Total Sales	684.4	772.5	873.2	1023.1	1097.0	1170.7	1207.9	1535.4
% Losses	21	23	23	23	24	24	27	27

Source: T.V. Long, The Rational Use of Energy in the Dominican Republic, report to the Inter-American Development Bank, 22 May 1979; and M.J. Perez, Características generales de las demanda y la oferta de energía, in CODIA 50.

Notes: ^aThere were discrepancies within M.J. Perez's report on the value of this figure. The estimate consistent with total generation was chosen here although it is not consistent with Table 11 of this report.

^bThese figures were estimated from the total hydro resource use quoted in Roberto Liz et al., Evaluación de la Situación Energética Nacional, Santo Domingo, July 1978.

tion.¹⁵ Finally, the generation efficiency of approximately 26 percent for the thermal plants is low, though this may be in part the result of using peaking plants for base load generation. With the net energy requirements of the CDE electric sector already accounting for almost 19 percent of total energy use in 1977 (see Table 18) and with CDE electricity sales growing at 12 percent a year (between 1970 and 1977), the inefficiencies in the electricity generation and delivery are of particular concern.

In addition to the electricity sales of the CDE, captive electricity generation within the industrial sector is apparently a widespread phenomenon. Unfortunately, there is very little documentation on the installed capacity and electricity generation within the industrial sector,¹⁶ although recent generation or sales data¹⁷ provide evidence that captive generation has been increasing rapidly in recent years, presumably the result of the frequent outages of the CDE system and the electricity price increases.

ENERGY CONSUMPTION PATTERNS

NOTES AND REFERENCES

1. World Bank, Dominican Republic, Its Main Economic Development Problems, 1978.
2. T. V.-Long, The Rational Use of Energy in the Dominican Republic, report to the Inter-American Development Bank, 22 May 1979.
3. Roberto Liz et al., Evaluacion de la Situacion Energetica National, Banco Central de la Republica Dominicana, Santo Domingo, 1978.
4. FAO, Yearbook of Forest Products, 1977.
5. Oficina Nacional de Estadistica, Estadistica Industrial de la Republica Dominica, 1975, Santo Domingo, 1975.
6. Oficina Nacional de Estadistica, unpublished material.
7. DELCANDA International Ltd., Technical-Economic Study of the Transport Sector, report to the Interamerican Development Bank, Dominican Republic, July 1978.
8. The population was approximately 4.98 million in 1977, and 4.3 million in 1972 (Reference 1, above).
9. T. V. Long, op. cit.
10. The first suggestion was made in Reference 7 above, the second in Reference 9.
11. T. V. Long, op. cit.
12. Figures from Oficina Nacional de Estadistica; Republica Dominica en Cifras, 1978.
13. It should be noted that there are a number of discrepancies in the electricity generation and capacity estimates from different sources which do not appear to be the result of different accounting procedures. For example, the electricity generation of the Tavera hydroelectric plants in 1975 is estimated at 225 and 93 million kWh in the Statistical Data Book of the USAID Mission to the Dominican Republic and M. J. Perez, Caracteristicas generales de las demanda y la oferta de energia, respectively. Similar discrepancies exist between other reports.
14. The capacity figures quoted here are from: T. V. Long, The Rational Use of Energy in the Dominican Republic and Roberto Liz et al., Evaluacion de la situacion Energetica National.
15. T. V. Long, ibid.
16. An estimate of the captive generation is given in section 3.2.1 of this report. As noted, however, this estimate is very tentative.

ENERGY CONSUMPTION PATTERNS

NOTES AND REFERENCES (continued)

17. The "emergency" generator sales between 1973 and 1977 (quoted in Roberto Liz et al., Evaluacion de la situacion Energetica Nacional, July 1978) were for 624 plants with a total capacity of over 100 MW_e, equivalent to approximately 20 percent of the effective capacity of the CDE system.

4. FUTURE ENERGY OUTLOOK

Any assessment of energy resource and technology options requires the projection of energy requirements at least 20 years into the future - the time required to implement any large-scale changes in the energy supply system. Ideally, such projections should provide a realistic view of the future economic and demographic situation of the country and should include a detailed analysis of the energy implications of the economic growth, the structural changes in the economy, the urban/rural population split, the resulting transportation requirements, and a number of other energy-relevant characteristics. In this overview, however, we have limited the projection to a macro-assessment of the future energy situation with the aim of providing reasonable scenarios from which general conclusions can be drawn.

In these projections the demand for commercial¹ and noncommercial fuels (i.e., wood, charcoal, and other biomass fuel) are assessed separately. The procedures and results of these projections are discussed in this section; the assumptions which were used in deriving the commercial demand projection parameters are given in Appendix B.

4.1 COMMERCIAL ENERGY DEMAND PROJECTIONS

The technique used to project the total commercial energy requirements to 1990 and 2000 is based on an assumed relationship between energy demand and economic growth and energy prices. This relationship is defined by the following equation:

$$D(t) = D(o) \left[\frac{GDP(t)}{GDP(o)} \right]^{IE} \left[\frac{PEN(t)}{PEN(o)} \right]^{PE}$$

where:

- D = commercial energy demand,
- GDP = gross domestic product in constant \$,
- PEN = average real price of delivered energy,
- IE = income elasticity of commercial energy demand,
- PE = price elasticity of commercial energy demand,
- (o) = base year,
- (t) = year t.

Since very little is known about price elasticities (especially in the long term) or the effect of rising energy costs on economic growth, projecting energy demand for a twenty year period is largely a matter of guesswork. The lack of data necessary to estimate income elasticities specific to the Dominican Republic further increases the level of uncertainty. With this in mind, we have developed alternative scenarios which indicate the order of magnitude of the range of uncertainty. The price effect is not incorporated in the Reference Case scenario which is developed first, primarily to provide a "business as usual" projection from which to work. To provide the sectoral breakdown and fuel mix of commercial energy demand in the Reference Case, exogenous projections of the residential and transportation fuel demand are employed (also derived under "business as usual" conditions), the "other" sector share and fuel mix are assumed to remain constant, and assumptions are made regarding the future fuel mix of the industrial sector and the level of

hydro utilization and overall efficiency of the electric sector. The sectoral shares and fuel demands of the electric and industrial sectors are implicit in these estimates and can be determined simultaneously.

A second case is then developed by incorporating an assumed growth rate in energy prices and a price elasticity for commercial energy demand. The sectoral shares and fuel mix are from the Reference Case, except that the absolute level of hydro-generation remains constant. While in practice the price elasticities of energy demand would be expected to vary between sectors and between fuels, the available data are not capable of supporting a disaggregated analysis.²

The resulting commercial energy demand estimates for 1990 and 2000 are presented by sector and fuel type in Tables 29 to 31. In the Reference Case, total commercial energy demand is projected to grow from 85.2×10^{15} joules in 1977 to 228.1×10^{15} joules in 1990 and to 486.5×10^{15} joules in the year 2000. Alternatively, in Case 2, the commercial energy demand grows to 195.7×10^{15} joules in 1990 and 371.2×10^{15} joules in 2000.

In both scenarios the sectoral shares of energy demand change significantly over this time period. The electric sector whose net energy demand share was 27 percent in 1977 accounts for 34 percent in the year 2000. While this represents a relatively large share of commercial energy use, the implicit annual growth rates for the electric sector of approximately 8.9 percent in the Reference Case and 7.6 percent in Case 2 are well below the electric sector growth rates projected on the basis of historical data (electricity sales grew at about 12 percent a year between 1970 and 1977). The shares of the industrial sector in final energy demand remain approximately constant, the principal change occurring in the fuel mix which is assumed to shift towards a

TABLE 29
COMMERCIAL ENERGY DEMAND - 1977
(10^{15} joules)

Fuel Sector	Oil	Hydro ^a	Electricity	Total Direct Use	Share (%)
Transportation	18.5	--	--	18.5	22
Residential	4.8	--	2.1	6.9	8
Industrial	31.3	--	2.1	33.4	39
Electric Sector	26.2	2.8	(-5.6)	23.4 ^c	27
Other	1.6	--	1.4	3.0	4
Total					
Resource Use ^b	82.4	2.8	--	85.2	100

Notes: ^aTaken as fossil fuel equivalent.

^bExcludes oil refining losses.

^cTaken as total resources consumed by utilities less electricity generated.

greater proportion of electricity. The shares of the residential and transportation sectors both fall slightly, with electricity also playing a greater role in the residential sector.

The national oil requirements, perhaps the most important aspect of the Dominican Republic's future energy situation, are shown to increase from 82.4×10^{15} joules in 1977 to 218.7×10^{15} joules in 1990 and to 462.5×10^{15} joules in 2000 in the Reference Case, implying an annual growth rate of 7.8 percent. Even in Case 2, oil use increases to 347.2×10^{15} joules in the year 2000, growing at an annual rate of 6.3 percent.

4.2 NONCOMMERCIAL ENERGY PROJECTIONS

At present, there is no standard or systematic way of projecting the consumption of noncommercial fuels, or of animal and human energy. The projection procedure adopted below is no more than an exercise in extrapolation using the best available information.

TABLE 30
COMMERCIAL ENERGY DEMAND PROJECTION - REFERENCE CASE
(10^{15} joules)

Fuel Sector	1990			Total Direct Use	Share (%)
	Oil	Hydro ^a	Electricity		
Transportation	43.5	--	--	43.5	19
Residential	9.6	--	5.2	14.8	6
Industrial	80.4	--	11.0	91.4	40
Electric Sector	80.9	9.4	(-19.9)	70.4 ^c	31
Other	4.3	--	3.7	8.0	4
Total					
Resource Use ^b	218.7	9.4	--	228.1	100
2000					
Transportation	84.2	--	--	84.2	17
Residential	14.3	--	8.5	22.8	5
Industrial	156.5	--	39.1	195.6	40
Electric Sector	198.4	24.0	(-55.6)	166.8 ^c	34
Other	9.1	--	8.0	17.1	4
Total					
Resource Use ^b	462.5	24.0	--	486.5	100

Notes: ^aTaken as fossil fuel equivalent.

^bExcludes oil refining losses.

^cTaken as total resources consumed by utilities less electricity generated.

TABLE 31
COMMERCIAL ENERGY DEMAND PROJECTION - CASE 2
(10¹⁵ joules)

Fuel Sector	1990			Total Direct Use	Share (%)
	Oil	Hydro ^a	Electricity		
Transportation	37.3	--	--	37.3	19
Residential	8.2	--	4.5	12.7	6
Industrial	69.0	--	9.4	78.4	40
Electric Sector	68.1	9.4	(-17.1)	60.4 ^c	31
Other	3.7	--	3.2	6.9	4
Total					
Resource Use ^b	186.3	9.4	--	195.7	100
2000					
Transportation	64.3	--	--	64.3	17
Residential	10.9	--	6.5	17.4	5
Industrial	119.4	--	29.8	149.2	40
Electric Sector	145.7	24.0	(-42.4)	127.3 ^c	34
Other	6.9	--	6.1	13.0	4
Total					
Resource Use ^b	347.2	24.0	--	371.2	100

Notes: ^aTaken as fossil fuel equivalent.
^bExcludes oil refining losses.
^cTaken as total resources consumed by utilities less electricity generated.

Two of the major noncommercial fuels, wood and charcoal, are used mainly for cooking in both the urban and rural areas with a small amount going to industrial areas. If we assume that consumption of noncommercial fuels in the urban sector and in industry will remain constant (in absolute terms) to the year 2000, any increase in the consumption of wood and charcoal will occur in the rural sector. In 1977, the rural population of the DR was about 2.68 million (see Section 1.0) and in the year 2000 the United Nations³ has projected that it will be about 4.34 million. This is in effect an average annual growth rate of 2.1 percent for the rural population during the period 1977-2000. In 1977, the rural population used 12.0 x 10¹⁵ joules of fuel energy for cooking - of which 62 percent came from wood, 24 percent from charcoal, 11 percent from kerosine, and 3 percent from LPG. If we assume that the relative shares of wood, charcoal, kerosine, and LPG in 2000 will be similar to those in 1977 and if we assume the implied 2.1 percent growth rate for the rural population, then the noncommercial energy requirements for rural cooking in 2000 will be about 16.7 x 10¹⁵ joules from wood and charcoal combined (see Table 35). Combining this with the urban household and industrial use of wood and charcoal yields a total of 20.7 x 10¹⁵ joules.

The energy content of available crop residues, with the exception of bagasse, amounted to 10.1×10^{15} joules in 1977 (see Table 15). If the growth rate of 2.1 percent (the average of the growth of major crops) is used to project total energy that may be obtained from crop residues, apart from bagasse, then this energy source could provide almost 16.3×10^{15} joules in 2000. In 1977, production of bagasse amounted to 3,899 metric tons, with energy content ranging from 27 to 43×10^{15} joules depending on the energy coefficient chosen (see Table 15). If we assume that bagasse production will increase at an average annual rate of 3.5 percent (the rate projected by SEA for sugarcane production during the period 1976-1986),⁴ then in 2000 the energy that could be supplied by bagasse would be in the range of 59 to 94×10^{15} joules.

The energy content of available animal dung was about 48×10^{15} joules in 1971 (see Table 16). Based on the country's average annual growth rate (3 percent) of livestock between 1961 and 1975 as reported in the United Nations Statistical Yearbook,⁵ animal dung, used either as cooking fuel or fertilizer, could contribute about 113×10^{15} joules to the energy needs of the rural population in the year 2000.

In 1975 there were about 3.1 million⁶ draft animals (cattle, horses, donkeys, mules) which consumed about 134,568 tons of corn, 10,136 tons of sweet potato, and 8,624 tons of cassava as feed.⁷ When the calorie value⁸ of these different feeds is taken into account, total food energy intake amounts to about 1908.4×10^6 joules. If consumption of these feeds (assuming no change in caloric value) grows at the same rate (3 percent) that is projected for livestock, then in the year 2000 draft animals can be expected to consume the equivalent of 3995.6×10^6 joules of feedstuffs. If we assume, as Revelle⁹ does, that energy utilized in animal work is about 40 percent of the food energy intake of draft animals, then in 2000 these animals could provide almost 1598×10^6 joules of useful energy.

FUTURE ENERGY OUTLOOK

NOTES

1. The term "commercial" energy generally refers to energy forms normally actively traded in developed country markets such as oil, gas, coal, and electricity. The primary categories of "noncommercial" energy are wood, agricultural wastes, and animal dung. The term "noncommercial" is in fact a misnomer, since there are monetary markets for these fuels. In some contexts, the term must be extended to include human and animal power. Other terms sometimes used for "noncommercial" are "traditional," "primitive" (vs "modern") or "nonconventional" (vs "conventional").
2. An attempt to estimate fuel and sector specific price and income elasticities from the available data in the Dominican Republic is given in T. V. Long, The Rational Use of Energy in the Dominican Republic.
3. United Nations, Trends and Prospects in Urban and Rural Population, 1950-2000 as assessed in 1973-74, p. 35, ESA/P/WP.54, April 25, 1975.
4. Secretaria De Estado De Agriculture, Diagnostico y Estrategia Del Desarrollo Agropecuario 1976-1986, p. 130.
5. United Nations, 1976 Statistical Yearbook, p. 116, New York, 1977.
6. United Nations, 1976 Statistical Yearbook.
7. Secretaria De Estado De Agricultura, Plan Operativo 1978, Anexo 1, Table 12.
8. The 1968 caloric values for corn (3.60 per gram), sweet potato (0.892 per gram), and cassava (1.08 per gram) were taken from "Hoja de Balance de Alimentos para la Republica Dominicana," No. 8, p. 8, Oficina Nacional De Estadistica, 1971.
9. Revelle, Roger, Requirements for energy in the rural areas of developing countries, in Norman L. Brown (Ed.), Renewable Energy Resources and Rural Applications in the Developing World, p. 13, Westview Press, Boulder, Colorado, 1978.

5. OBSERVATIONS AND CONCLUSIONS

In this preliminary assessment of energy supply and demand, a number of areas have been identified which will have an important effect on the future role of energy in meeting the Dominican Republic's developmental goals. The key concern is undoubtedly the role of imported petroleum. Others include the need for more complete and systematic data and information on potential domestic energy resources and on the underlying determinants of future energy demand in various sectors of the nation's economy.

In the context of developing economies, the demand for energy arises from the essential role energy performs in raising productivity and contributing to growth and development as well as in meeting basic needs such as cooking and lighting. The "business-as-usual" scenario we have projected for energy demand in the Dominican Republic takes into account current and projected demographic patterns as well as identified industrial and agricultural trends and policies. Under this scenario, total energy consumption is projected to rise to about 590×10^{15} joules in the year 2000. Taking current domestic energy resource development trends into consideration, 82 percent of this demand will have to be met with imported oil. This implies a level of imports of about 215,000 barrels per day which, even at a very conservative estimate of \$50/barrel in 2000, will mean an import bill of almost 4 billion dollars a year. It is clear that even with optimistic projections of future sugar exports and prices, this level of imports will be very difficult to maintain.

Increasing energy system utilization efficiency to provide the same levels of service with smaller amounts of fuel use is clearly an important priority. However, the information base on which a future scenario of efficiency improvements could be determined at the sectoral and subsectoral level is lacking. Indeed, even current sectoral energy consumption levels need a great deal of further documentation, especially in the industrial sector where the data base is poor. Losses in electrical transmission and distribution are very high for the small size of the DR integrated grid and the need for improvements here have been commented on by other observers.¹ Our projections include significant reductions in transmission and distribution losses from a current level of approximately 27 percent down to 17 percent by 2000.

Projections of future energy consumption from the inadequate data base that currently exists are, no doubt, subject to many uncertainties. Projections by other observers, particularly at the sectoral level, are also subject to problems of intersectoral consistency especially as they use sectoral income elasticities on the basis of scanty and unreliable data. A systematic process of data collection efforts on current and historical levels of energy use in different sectors should be a priority task.

The known domestic energy resources of the DR are inadequate to support levels of projected development. However, efforts to plan their rational utilization, given the oil situation, need priority. Hydro power, especially, has not been properly utilized so far. The fact that of the 136 MW of installed capacity only about 40 MW is currently available because of releases of water for irrigation suggests that considerable strengthening of planning capability is needed in the water resources sector. The known levels of deforestation suggest that percent levels of noncommercial fuels in use are already approaching their natural sustainable limits. The potential use of peat and lignite deposits needs further investigation.

Finally, energy use in the food system is virtually undocumented in the DR. Preliminary estimates are provided in Appendix C, but the high level of uncertainty limits their usefulness. (These estimates were not used in earlier portions of the assessment partly because of conflicts with the data used in other demand sectors.) Supplying the basic food requirements of the growing population is obviously of principal importance and, while the agricultural sector is not a large energy consumer at present, increasing crop production under severe land constraints is generally a fairly energy-intensive process. Future stages of this study should provide insights into the role of energy in the food system within the context of the country's energy situation as a whole.

OBSERVATIONS AND CONCLUSIONS

NOTES AND REFERENCES

1. For example, T. V. Long, The Rational Use of Energy in the Dominican Republic, report to the Inter-American Development Bank, 22 May 1979.

APPENDIX A

DOMINICAN REPUBLIC REFERENCE ENERGY SYSTEM

The Reference Energy System (RES) presented in this appendix represents an integrated picture of the energy supply-demand pattern in the Dominican Republic. It consists of the estimated energy demands by specific end use described in Chapters 3 and 4, energy conversion technology, fuel mixes, and, ultimately, resources used to satisfy these demands. Associated with each energy flow or branch in the RES network is a series of coefficients of three types: efficiency, environmental, and economic. At present, only a limited set of efficiencies and flows have been developed for the Dominican Republic. An expanded and computerized version of this RES can be used for evaluating the energy system impacts of policy (conservation, fuel substitution, pricing, etc.) and technological options.* The reference energy systems for 1977 and 2000, presented in this appendix do not incorporate any significant changes in the energy supply system's structure.

*For a more detailed description of the RES approach to energy systems analysis, one may refer to: An Analytical Framework for the Assessment of Energy Resource and Technology Options, BNL-50800, Feb. 1978.

NOTES:
 1. FLOWS IN 10^{18} JOULES
 2. SOLID LINE INDICATES REAL PROCESS
 3. CONVERSION EFFICIENCIES SHOWN IN PARENTHESIS
 4. HYDRO RESOURCE USE MEASURED IN FOSSIL FUEL EQUIVALENT

Figure 2. Dominican Republic Reference Energy System (1977)

NOTES:
 1. FLOWS IN 10^{12} JOULES
 2. SOLID LINE INDICATES REAL PROCESS
 3. CONVERSION EFFICIENCIES SHOWN IN PARENTHESIS
 4. HYDRO RESOURCE USE MEASURED IN FOSSIL FUEL EQUIVALENT

Figure 3. Dominican Republic Reference Energy System
 (2000) = Reference Case

- NOTES:
1. FLOWS IN 10^{12} JOULES
 2. SOLID LINE INDICATES REAL PROCESS
 3. CONVERSION EFFICIENCIES SHOWN IN PARENTHESIS
 4. HYDRO RESOURCE USE MEASURED IN FOSSIL FUEL EQUIVALENT

Figure 4. Dominican Republic Reference Energy System
(2000) - Case 2

APPENDIX B

COMMERCIAL ENERGY PROJECTION ASSUMPTIONS

The assumed values of the parameters employed in the projection of total commercial energy demand are given in Table 32. Table 33 lists the assumptions which provided the basis for estimating the sectoral breakdown and fuel mix in the Reference Case. For Case 2 the sector shares and fuel mix were assumed equal to the Reference Case except that the level of hydro utilization was kept at the same absolute level. Finally, Tables 34-39 describe in detail the assumptions and results of the Reference Case residential projection.

TABLE 32

COMMERCIAL ENERGY DEMAND PROJECTION ASSUMPTIONS

Parameter	Reference Case 1977 - 2000	Scenario 2 1977 - 2000
Income Elasticity ^a	1.3	1.3
Price Elasticity ^b	--	- 0.3
Annual GDP Growth Rate (real) ^c	6%	6%
Annual Energy Price Growth Rate (real)	--	4%

^aFrom A. Lambertini, Energy and Petroleum in Non-OPEC Developing Countries, 1974-1980, World Bank Staff Working Paper No. 224, February 1975. For a discussion of income elasticities of energy demand see P. F. Palmedo et al., Energy Needs, Uses and Resources in Developing Countries, BNL 50784, March 1978.

^bFrom World Bank Development Policy Staff, Prospects for Developing Countries, 1978-85, November 1977.

^cApproximate average annual growth rate of real GDP, 1960-77. See World Bank, Dominican Republic: Its Main Economic Development Problems, December 1978.

TABLE 33

ASSUMPTIONS FOR REFERENCE CASE
SECTORAL BREAKDOWN OF COMMERCIAL ENERGY DEMAND

1. The Residential shares and fuel mix are based on the Fuel Mix Tables described below.
 2. The Transportation share is based on the projections derived in the Delcanda Study, Technical-Economic Study of the Transport Sector, Dominican Republic, July 1978.
 3. The Other sector share and fuel mix are assumed to remain constant to the year 2000.
 4. The industrial sector fuel mix is assumed to be 12 percent electricity and 88 percent oil-based fuel in 1990 and 20 percent electricity and 80 percent oil-based fuels in the year 2000. (The industrial share is determined simultaneously to the electric sector given assumption 5.)
 5. The electric system is assumed to have an overall efficiency of 0.2 in 1990 and 0.25 in the year 2000. By 2000, 80 percent of the identified hydrogeneration potential is realized, 31 percent having been realized by 1990.
-

Residential Energy Demand Reference Case Projections

The Residential fuel demands are projected with the aid of the fuel mix tables 34 to 39. The variables in these tables are defined below:

FUEL DEMAND, D_i = The quantity of a fuel, i , actually consumed in a specific demand category, such as when cooking or lighting.

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

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

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

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

SATURATED BASIC ENERGY DEMAND = The Basic Energy Demand that would exist in a category if there was 100% saturation, $= E/S$.

UNIT BASIC ENERGY DEMAND = The Basic Energy Demand per household.

FUEL FRACTION, f = Fraction of the Saturated Basic Energy Demand that is satisfied by using the i 'th fuel.

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

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

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

TABLE 34
TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Urban Cooking

Fuel	1977			1990			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
LPG	0.60	0.6	2.2	0.80	0.6	6.1	0.87	0.6	10.3
Charcoal	0.38	0.3	2.8	0.18	0.3	2.8	0.12	0.3	2.8
Wood	0.02	0.2	0.2	0.01	0.2	0.2	0.01	0.2	0.2
Total Fuel Demand ($10^{15}J$)			5.2			9.1			13.3
Basis (10^3 Hshlds)	354.4			737			1,148		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10^9J)	6.2			6.2			6.2		

Notes: The 1977 fuel consumption estimates are based on an unpublished survey of household expenditures (Banco Central de la Republica Dominicana, Encuesta de Ingresos y Gastos de las Familias, Mayo 1976 - April 1977) and prices provided by the Banco Central. LPG price was adjusted upward to ensure that household consumption did not exceed total sales. Electric cooking, which could not be separated out from other electricity use, is incorporated in electric appliances.

Projections assume constant Unit Basic Demand and constant wood and charcoal consumption in urban areas to the year 2000.

TABLE 35

TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Rural Cooking

Fuel	1977			1990			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
LPG	0.06	0.6	0.3	0.06	0.6	0.4	0.06	0.6	0.5
Kerosene	0.17	0.4	1.3	0.17	0.4	1.8	0.17	0.4	2.1
Charcoal	0.28	0.3	2.9	0.28	0.3	4.0	0.28	0.3	4.6
Wood	0.49	0.2	7.5	0.49	0.2	10.4	0.49	0.2	12.1
Total Fuel Demand ($10^{15}J$)			12.0			16.6			19.3
Basis (10^3 Hshlds)	494			685			798		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10^9J)	6.2			6.2			6.2		

Notes: The 1977 fuel consumption figures were estimated in a manner similar to that used for urban cooking except that:

1. Wood consumption was adjusted upward to account for the remaining total wood consumption (from Table 17 of this report) after industrial and urban wood and charcoal consumption had been allocated.
2. Kerosene was introduced up to the point where the rural unit basic demand equalled the urban unit basic demand.

Projections assume constant shares and constant Unit Basic Demand to the year 2000.

TABLE 36

TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Urban Lighting

	1977			1990			2000		
Fuel	f _i	e _i	D _i	f _i	e _i	D _i	f _i	e _i	D _i
Electricity	0.68	1	0.11	0.8	1	0.26	0.85	1	0.43
Kerosene	0.32	0.25	0.2	0.2	0.25	0.26	0.15	0.25	0.30
Total Fuel Demand (10 ¹⁵ J)			0.31			0.52			0.73
Basis (10 ³ Hshlds)	354.4			737			1,148		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10 ⁹ J)	0.44			0.44			0.44		

Notes: For 1977 estimates, the residential electricity consumers were allocated to urban and rural areas in proportion with their expenditures on electricity (from Banco Central de la Republica Dominicana, Encuesta de Ingresos y Gastos de las Familias). All nonelectrified households were assumed to use kerosene for lighting. The level of kerosene consumption (after accounting for kerosene cooking) and the efficiency of the kerosene lighting was then used to determine the unit basic demand for lighting. The lighting of electrified households in excess of this unit basic demand was implicitly assigned to electric appliances.

The projections assume 85% electrification by the year 2000.

TABLE 37

TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Rural Lighting

Fuel	1977			1990			2000		
	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
Electricity	0.08	1	0.02	0.15	1	0.05	0.2	1	0.07
Kerosene	0.92	0.25	2.8	0.85	0.25	1.02	0.8	0.25	1.12
Total Fuel Demand ($10^{15}J$)			4.82			1.07			1.19
Basis (10^3 Hshlds)	494			685			798		
Saturation	1.0			1.0			1.0		
Unit Basic Demand: (10^9J)	0.44			0.44			0.44		

Notes: See Table 36.

TABLE 38
TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Urban Appliances

	1977			1990			2000		
Fuel	f _i	e _i	D _i	f _i	e _i	D _i	f _i	e _i	D _i
Electricity	0.68	1	1.69	0.80	1	4.12	0.85	1	6.83
Total Fuel Demand (10 ¹⁵ J)			1.69			4.12			6.83
Basis (10 ³ Hshlds)	354.4			737			1,148		
Saturation	0.68			0.80			0.85		
Unit Basic Demand: (10 ⁹ J)	7.0			7.0			7.0		

Notes: All urban electricity consumption for 1977 in excess of electric lighting was assigned to appliances.

TABLE 39

TENTATIVE FUEL MIX TABLE

Sector: Residential
End Use: Rural Appliances

	1977			1990			2000		
Fuel	f_i	e_i	D_i	f_i	e_i	D_i	f_i	e_i	D_i
Electricity	0.08	1	0.28	0.15	1	0.72	0.20	1	1.12
Total Fuel Demand ($10^{15}J$)			0.28			0.72			1.12
Basis (10^3 Hshlds)	494			685			798		
Saturation	0.08			0.15			0.20		
Unit Basic Demand: (10^9J)	7.0			7.0			7.0		

Notes: All 1977 rural electricity consumption in excess of rural electric lighting was assigned to rural appliances.

APPENDIX C
DOMINICAN REPUBLIC
TENTATIVE CROP PROFILES AND ENERGY INPUT ANALYSIS

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August, 1979

As noted in the preface, this assessment will eventually be part of a larger study focusing on the role of energy in the food system. Appendix C provides a very preliminary account of the energy inputs to the production, transportation, and processing of sugarcane and some of the principal food crops. Since no detailed DR data (with the possible exception of fertilizer usage) are available on the energy inputs to the food system, the energy coefficients are, for the most part, based on studies carried out in the United States and elsewhere. Although attempts have been made to adjust the coefficients to account for the different agricultural techniques in the DR, the resulting estimates remain very uncertain. Future stages of this study will attempt to eliminate the uncertainties and inconsistencies within the food system through the use of surveys and other forms of data estimation procedures in the field.

RICE						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	214,000	---	---	43.5	9,300	189,200
2.0 Threshing						
2.1 Hand	14,531	449	3	0	0	0
2.2 Portable Machine	14,531	449	3	25	363	2,971
2.3 Fixed Machine	178,519	5,521	3	5	893	7,300
3.0 Drying	201,354	6,227	3	0	0	0
4.0 Storage	195,313	6,041	3	0	0	0
5.0 Milling						
5.1 Hand Milling	25,873	1,362	5	0	0	0
5.2 Machine Milling	156,334	8,228	5	14	2,189	17,901
6.0 Transport						
6.1 Nonmotorized	54,717	0	0	0	0	0
6.2 Motorized	101,616	0	0	1.0 (9.6 km)	99	810
6A Nontransported						
6A1 On-farm consumption	20,954	0	0	0	0	0
6A2 Seed	3,516	0	0	0	0	0
6A3 Lost/stolen or unsold	4,920	0	0	0	0	0
TOTAL	195,723	28,277	15	57.3	10,655	200,281

Rice Footnotes

- 1.0 Production: See production data sheet. Preharvest losses from:
Cramer, H.H. 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of
Farbenfabriken Bayer AG, Leuerkusen, p. 106.
- Losses due to: insect pests = 3.4%
 diseases = 6.4%
 weeds = 11.2%
- 2.0 Threshing: Losses due to threshing from: National Academy of Sciences.
1978. Postharvest Food Losses in Developing Countries, p.
64. It was assumed that since 86% of the final crop is
marketed (Census SWD#2B, PRD-CULT-10A), 86% of the crop was
threshed by fixed machine, with the remaining 15% threshed
by either hand or portable machine. The energy inputs for
threshing were from the Senegal study, p. 4:36.
- 3.0 Drying: Losses from NAS study p. 64 [see footnote 2.0].
- 4.0 Storage: Losses from NAS study, p. 64.
- 5.0 Milling: Losses from NAS study, p. 64. It was assumed that the
14.2% of the rice crop which is consumed on the farm (Census
SWD #2B, PRD-CULT-10A) is hand milled with the remaining
being machine milled. Energy inputs for milling were from
the Senegal study.
- 6.0 Transport: Percentage of motorized vs nonmotorized transport from
Census SWD #5-MRC-CULT-1. Average distance to market of 9.6
km also from Census SWD#5-MRC-CULT-1. Energy inputs based
upon an average of 830 kcal/tonne/km to transport goods by
truck (From: D. Pimentel Energy used for transporting
supplies to the farm, in D. Pimentel (Ed.) 1979, Energy
Utilization in Agriculture, CRC Press, Boca Raton, Florida,
in press).
- The figure of 8,179 kcal/liter of gasoline is from Table
C-1: Energy supplies and efficiency, also in the CRC book.
- 3A Nontransported: Percentages of rice which are not transported from the
farm were obtained from Census SWD #28 PRD-CULT-10A.

CASSAVA						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	198,000	---	---	14.5	2,871	24,273
2.0 Storage	150,000	48,000	24	0	0	0
3.0 Transport						
3.1 Nonmotorized	45,872	0	0	0	0	0
3.2 Motorized	40,678	0	0	0.7 (7.0 km)	28.8	236
3A Nontransported						
3A ₁ On-farm consumption	57,300	0	0	0	0	0
3A ₂ Animal Feed	3,600	0	0	0	0	0
3A ₃ Lost/stolen or unsold	2,550	0	0	0	0	0
TOTAL	150,000	48,000	24	19.3	2,900	24,509

Cassava Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farbenfabriken Bayer AG, Leuerkusen, p. 266.
- 2.0 Storage: Losses based upon data from Dominican Republic. From: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, p. 112.
- 3.0 Transport: Percentages of motorized vs nonmotorized transport from Census SWD #5 MRC-CULT-1. Average distance to market of 7.0 km also from Census SWD #5 MRC-CULT-1. Energy inputs based upon an average of 830 kcal/tonne/km to transport goods by truck (From: D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.), 1979. Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press).
- 3A Nontransported: Percentages of cassava which are not transported from the farm were obtained from Census SWD #2B PRD-CULT-10A.

BEANS

Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	32,550	---	---	90	2,919	24,517
2.0 Storage & Drying	22,800	9,750	30	0	0	0
3.0 Transport						
3.1 Nonmotorized	8,219	0	0	0	0	0
3.2 Motorized	8,219	0	0	1.4 (13.4 km)	11.1	91
3A Nontransported						
3A ₁ On-farm consumption	4,469	0	0	0	0	0
3A ₂ Animal Feed	46	0	0	0	0	0
3A ₃ Lost/stolen or unsold	1,003	0	0	0	0	0
3A ₄ Seed	844	0	0	0	0	0
TOTAL	22,800	9,750	43	128	2,930	24,608

Bean Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farben-Fabriken Bayer AG, Leuerkusen, p. 266.
- Losses due to: insect pests = 13.3%
diseases = 11.3%
weeds = 8.7%
- 2.0 Storage & Drying: Losses based upon data from South and Central American Countries. From: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, p. 93.
- 3.0 Transport: Percentages of motorized vs nonmotorized transport from Census SWD #5 MRC-CULT-1. Average distance to market of 13.4 km also from Census SWD #5 MRC-CULT-1. Energy inputs based upon an average of 830 kcal/tonne/km to transport goods by truck (From: D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.) 1979. Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press). The figure of 8,179 kcal/liter of gasoline is from Table C-1: Energy supplies and efficiency, also in the CRC book.
- 3A Nontransported: Percentages of beans which are not transported from the farm were obtained from Census SWD #2B PRD-CULT-10A.

SUGARCANE						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	10,740	---	---	28.7	26,069	671,294
2.0 Transport						
2.1 Motorized	10,740	0	0	unknown	unknown	unknown
3.1 Processing						
3.1 Sugar Milling	1,257	Sugar		704	885,340	7,241,179
	290	Molasses				
	537	Bagasse				
	322	Filter mud				
TOTAL	1,257	Sugar		732.7+	36,954+	678,535+
	290	Molasses				
	537	Bagasse				
	322	Filter mud				

Sugarcane Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farben-Fabriken Bayer AG.
- 2.0 Transport: Assumed that all transport of sugarcane is by motorized transport. Average distance to market is unknown, therefore unable to determine energy inputs. Similarly, postharvest losses are also unknown.
- 3.0 Processing: Yield of 117 kg of refined sugar per tonne of sugarcane from: World Bank Country Study. Dominican Republic, Its Main Economic Development Problems, December 1978.

By-product yields:

50 kg surplus Bagasse (at 49% moisture)/tonne of sugarcane
27 kg molasses (89 Brix; sp.gr. 1.47)/tonne of sugarcane
30 kg filter mud (at 80% moisture/tonne of sugarcane)

From: Paturau, J.M., 1969, By-Products of the Cane Sugar Industry. Elsevier Publishing Company, Amsterdam, London, N.Y., p. 6.

The figures are based upon the following assumptions: sucrose % cane, 13.0; fibre % cane, 13.0; mill extraction, 95%; overall efficiency, 85%; purity of mixed juice, 84.0; steam consumption, 500 kg per tonne of cane; 2.3 tonnes of steam generated per tonne of wet bagasse.

Energy inputs are from: Pimentel, D. and M. Pimentel, 1979, Food, Energy and Society, Edward Arnold Publishers, London, p. 116. They were adjusted for a sugar content of 11.7%. Kcal figures were converted to liter equivalents based upon a conversion of 8,179 kcal/liter of gasoline from Table C:1 Energy supplies and efficiency, in D. Pimentel (Ed.) 1979, Energy Utilization in Agriculture. CRC Press, Boca Raton, Florida (in press).

SWEET POTATO

Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	100,000	---	---	11.0	1,098	9,101
2.0 Storage	70,000	30,000	30	0	0	0
3.0 Transport						
3.1 Nonmotorized	18,930	0	0	0	0	0
3.2 Motorized	28,390	0	0	0.75 (7.4 km)	21.3	174
3A Nontransported						
3A ₁ On-farm consumption	19,460	0	0	0	0	0
3A ₂ Animal Feed	2,100	0	0	0	0	0
3A ₃ Lost/stolen or unsold	1,120	0	0	0	0	0
TOTAL	70,000	0	30	16.0	1,119	9,275

Sweet Potato Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farbenfabriken Bayer AG, Leuerkusen, p. 266.
- Losses due to: insect pests = 5.7%
diseases = 15.6%
weeds = 2.9%
- 2.0 Storage: Losses based upon data from South and Central American countries and other LDC's. From: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, pp. 112-112.
- 3.0 Transport: Percentages of motorized vs. non-motorized transport from Census SWD #5 MRC-CULT-1. Average distance to market of 7.4 km also from Census SWD #5 MRC-CULT-1. Energy inputs based upon an average of 830 kcal/tonne/km to transport goods by truck (From: D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.) 1979. Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press). The figure of 8,179 kcal/liter of gasoline is from Table C-1: Energy supplies and efficiency, also in the CRC book.
- 3A Nontransported: Percentages of cassava which are not transported from the farm were obtained from Census SWD #2B PRD-CULT-10A.

PEANUTS						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	81,763	---	---	19	1.547	23,013
2.0 Threshing						
2.1 Hand Threshing	34,898	1,079	3	0	0	0
2.2 Machine Threshing	44,413	1,373	3	5	222	1,816
3.0 Drying						
3.1 Sun drying	77,725	1,586	2	0	0	0
4.0 Storage						
4.1 All storage combined	74,616	3,109	4	0	0	0
5.0 Transport						
5.1 Non-motorized	32,436	0	0	0	0	0
5.2 Motorized	39,643	0	0	1.1 (10.7 km)	43	352
5A Nontransported						
5A ₁ On-farm consumption	2,462	0	0	0	0	0
5A ₂ Lost/stolen	75	0	0	0	0	0
6.0 Processing						
6.1 Oil milling	71,358	0	0	1.9	134	1,096
6.2 Shelling	721	0	0	unknown	unknown	unknown
TOTAL	74,616	7,147	9.5	26+	1,946+	26,277+

Peanuts Footnotes

- 1.0 Production: See production data sheet
Pre-harvest losses of 36.2% as follows:
insects:	4.4%
diseases:	20.7%
weeds:	11.1%
- Data from Groundnut losses for North and Central America.
In: H.H. Cramer, 1967, Plant Protection and World Crop Production, Farbenfabriken, Bayer AG, Leuerkusen.
- 2.0 Threshing and Losses for threshing and drying of 5% from Senegal study
3.0 Drying: (assumes 2% for drying and 3% for threshing). For machine threshing, 5 liters of fuel per tonnes is assumed usage. From Senegal study data for rice threshing. Fuel energy equivalent: 1 liter of gasoline contains 8.179 kcal of energy. (From D. Pimentel, 1979. For reference see footnote 6 of production footnotes). Assumes production of 1.1, 1.2, 1.5, 1.6 is machine-threshed and production of 1.3, 1.4, 1.7, 1.8 is hand threshed.
- 4.0 Storage: Assumes 4% losses as follows: Average postharvest loss from NAS study: 9%
Less threshing and 5%
Storage loss 4%
- Losses from NAS study: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, NAS, Washington, D.C.
- 5.0 Transport: Percentages for motorized and nonmotorized transport from Census SWD #5 Table MRC-CULT-1. Average distance transported = 10.7 km. From SWD #5 Table MRC-CULT-1.
- Energy used: 0.83 kcal/kg/km. From D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.), 1979, Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press.
- 0.83 kcal/kg/km = 830 kcal/tonne/km
- 830 kcal/tonne/km - .10 l. gas/tonne/km. (assumes 1 l. gas contains 8,179 kcal of energy -- see threshing/drying footnote for reference).
- 5A Not transported: Percentages for these usages, and hence amounts, obtained from Census SWD #2B, table PRD-CULT-10A.

6.0 Processing:

Assumes from Senegal study, that 1% of available production goes to shelled nuts, and that 99% goes to oil milling.

Shelling: not available
Oil Milling: 1.7 l gas/tonne
 1.7 kWh/tonne
 From Senegal study

From Table C-1: Energy Utilization in Agriculture, by D. Pimental

1.7 l. gasoline/tonne:	13904 kcal/tonne
1.7 kWh/tonne =	1460 kcal/tonne
TOTAL:	15364 kcal/tonne for oil milling

1.7 kWh .18 l gas equivalent. Therefore, total equivalent amount of liquid fuel for oil milling = $1.7 \times 0.18 = 1.88$.

PLANTAIN						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Units x 10 ⁶	Losses in Units x 10 ⁶	Losses %	Liters Fuel per Unit x 10 ⁶	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	3,000	---	---	1459	4,377	39,699
2.0 Storage	2,700	300	10	0	0	0
3.0 Transport						
3.1 Nonmotorized	773	0	0	0	0	0
3.2 Motorized	685	0	0	Unknown	Unknown	Unknown
3A Nontransported						
3A ₁ On-farm consumption	1,212	0	0	0	0	0
3A ₂ Animal Feed	3	0	0	0	0	0
3A ₃ Lost/stolen or unsold	27	0	0	0	0	0
TOTAL	2,700	300	10	1621+	4,377+	39,699+

Plantain Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farbenfabriken Bayer AG, Leuerkusen, p. 286. Assumes that losses in plantains same as those which occur in bananas.
- Losses due to: insect pests = 5%
diseases = 25%
weeds = 3%
- 2.0 Storage: Losses based upon data from Dominican Republic. From: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, p. 112.
- 3.0 Transport: Percentages of motorized vs nonmotorized transport from Census SWD #5 MRC-CULT-1. Average distance to market of 7.4 km also from Census SWD #5. Energy inputs unknown due to lack of information regarding weights of "units."
- 3A Nontransported: Percentages of plantains which are not transported from the farm were obtained from Census SWD #2B PRD-CULT-10A.

TOMATOES						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Liters Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	86,316	---	---	13.4	1157.5	9,467
2.0 Storage						
2.1 All storage systems	80,274	6,042	7	0	0	0
3.0 Transport						
3.1 Motorized	42,925	2,740	6	1.36	58.4	485
3.2 Nonmotorized	32,382	2,067	6	0	0	0
3A Nontransported						
3A ₁ On-farm consumption	80	0	0	0	0	0
3A ₂ Lost/stolen or unused	80	0	0	0	0	0
4.0 Processing						
4.1 Industrial tomato processing	75,081	0	0	Unknown	Unknown	Unknown
4.2 Salad tomatoes	226	0	0	0	0	0
TOTAL	75,467	10,849	12.5	16.1+	1216+	9,952+

Tomatoes Footnotes

1.0 Production: See production data sheet.

2.0 Preharvest losses: of 30.1% as follows:

Insects: 4.4%
Diseases: 20.7%
Weeds: 11.1%

Based on losses from South American tomato production. In H.H. Cramer, 1967, Plant Protection and World Crop Production, Farbenfabriken Bayer AG.

3.0 Storage: Assumes one basic system of storage. NAS study gives 13% as post-harvest loss for tomato production in Dominican Republic. Assumes 7% of loss occurs in storage and remaining 6% of loss occurs in transport. NAS source: National Academy of Sciences, 1978, Postharvest Food Losses in Developing Countries, NAS, Washington, D.C.

4.0 Transport: Percentages for motorized and non-motorized transport from Census SWD #5 Table MRC-CULT-1. Average distance transported = 13.6 km. From Census SWD #5 Table MRC-CULT-1.

Energy used: 0.83 kcal/kg/km. From: D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.), Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press.

0.83 kcal/kg/km - 830 kcal/tonne/km.
830 kcal/tonne/km = .10 l gas/tonne/km. (assumes 1 l of gas contains 8179 kcal of energy). For reference, see footnote #6 in production footnotes.

Transportation-related losses of 6% from NAS source for Dominican Republic tomato data. For reference and further explanation, see above footnote for storage.

4A Nontransported: Percentages for these usages and hence amounts, obtained from Census SWD #2B table PRD-CULT-10A.

5.0 Processing: Percentages, and hence amounts, of fresh tomato production vs processed tomato production were obtained from the Census SWD #2 Table PRD-CULT-1.

Note: the nature of the processing and final products for "Industrial tomatoes" was not known. Therefore, the output for this system is simply titled, "Processed Tomatoes," and the output quantity is identical to the input quantity (i.e., it is assumed that there are no losses in this system). Also, for this reason, energy inputs for industrial tomato processing are listed as unknown.

CORN						
Activity	OUTPUTS AND LOSSES			ENERGY INPUTS		
	Net Output Tonnes	Losses in Tonnes	Losses %	Fuel per Tonne	Total Fuel 10 ³ Liters	Total kcal x 10 ⁶
1.0 Production	49,942	---	---	108	5,415	47,038
2.0 Storage & Drying	39,953	9,988	20	0	0	0
3.0 Transport						
3.1 Nonmotorized	15,534	0	0	0	0	0
3.2 Motorized	13,232	0	0	1.2 (11.7 km)	15	128
3A Nontransported						
3A1 On-farm consumption	5,034	0	0	0	0	0
3A2 Animal Feed	4,954	0	0	0	0	0
3A3 Lost/stolen or unsold	759	0	0	0	0	0
3A4 Seed	439	0	0	0	0	0
TOTAL	39,953	9,988	20	135	5,430	47,166

Corn Footnotes

- 1.0 Production: See production data sheet. Pre-harvest losses from: Cramer, H.H., 1967, Plant Protection and World Crop Production. Crop Protection Advisory Department of Farbenfabriken Bayer AG, Leuerkusen, p. 266.
- Losses due to: insect pests = 20%
diseases = 10%
weeds = 10%
- 2.0 Storage & Losses based upon data from Dominican Republic and other American countries. From: National Academy of Sciences, 1978. Postharvest Food Losses in Developing Countries.
- 3.0 Transport: Percentages of motorized vs. non-motorized transport from Census SWD #5 MRC-CULT-1. Average distance to market of 11.7 km also from Census SWD #5 MRC-CULT-1. Energy inputs based upon an average of 830 kcal/tonne/km to transport goods by truck (from: D. Pimentel, Energy used for transporting supplies to the farm, in D. Pimentel (Ed.) 1979. Energy Utilization in Agriculture, CRC Press, Boca Raton, Florida, in press).
- 3A Nontransported: Percentages of beans which are not transported from the farm were obtained from Census SWD #2B PRD-CULT-10A.

Production Footnotes

1. Hectarage:

- (a) Total from Table 8 (1974 data) of TVA study:

J. Free, C. Kresge, and T. H. Foster, Dominican Republic Fertilizer Situation--A Description, Analysis, and Recommendation, National Fertilizer Development Center Bulletin 4-103, Tennessee Valley Authority, Muscle Shoals, Ala., January 1976.

- (b) Relative percentages of fertilized and unfertilized land based upon Table 8 of TVA study.

- (c) Relative percentages of interplanted and not interplanted crop land based upon data from:

U.S. Agency for International Development, Dominican Republic Agricultural Sectoral Analysis Series: Statistical Working Document 2-B, Table PRD-CULT-5, U.S. Bureau of the Census, Washington, D.C., 1977.

- (d) Note: it was assumed that production techniques 1.1 and 1.5 were each employed on less than 1% of the hectarage.

2. Yield:

- (a) Based upon Tables 12 and 13 of TVA study (see footnote 1a).

3. Production:

- (a) Area (ha) x Yield (kg/ha). Checked against TVA study, Table 3 (1972 production figures). For reference, see footnote 1a.
[Note: for plantains only, both yield and production data are given in terms of "units" rather than kilograms].

4. Fertilizer:

- (a) Fertilizer usage data from TVA study, Table 11 (see footnote 1a for complete reference).

5. Fertilizer:

- (a) Total tonnes = area x usage/ha.

6. Fertilizer Energy:

Assumes following values for energy consumption embodied in fertilizer:

- (a) Nitrogen: 13,900 kcal/kg

- (b) Phosphorus: 2,400 kcal/kg

- (c) Potassium: 1,300 kcal/kg

From Lockeretz in: D. Pimental (Ed.) 1979, Energy Utilization in Agriculture, CRC Press, Boca Raton, Fla., in press.

7. Fuel usage for highly mechanized technique based upon following:

- (a) Plantains: manuscript by F. W. Liu, Dept. of Pomology, Cornell University: Energy requirements for banana production in selected areas, value of 150 l/ha from Taiwanese data for banana production.
- (b) Tomato: 628 l/ha from data on U.S. tomato production in: D. Pimentel, 1979, Food, Energy, and Society, Edward Arnold (Publishers) Ltd., London.
- (c) Cassava: 150 l/ha. Estimated by D. Pimentel.
- (d) Peanuts: 63 l/ha. From data for U.S. peanut production. From D. Pimentel, 1979. (See footnote 7b for complete reference.)
- (e) Corn: 206 l/ha. From data for U.S. corn production in: D. Pimentel, 1979, The energy crisis: its impact on agriculture. Scienza & Technica 76, Mondadori, Milan, in press.
- (f) Beans: 178 l/ha. From data for U.S. potato production. (For reference, see footnote 7e).
- (g) Sweet Potatoes: 206 l/ha. From data for U.S. potato production. (For reference, see footnote 7e).
- (h) Rice: 225 l/ha. From data for U.S. rice production. (For reference, see footnote 7e).
- (i) Sugar Cane: 338 l/ha. From data for sugarcane production in Louisiana. In Energy Inputs and Output for Sugarcane in Louisiana. Manuscript by Ray Ricaud, Louisiana Agricultural Experiment Station, Baton Rouge, Louisiana.

[Note: it is assumed that fuel usage for partially mechanized systems is half of that for the fully mechanized system. Furthermore, it is assumed that fuel usage for nonmechanized cropping systems is zero].

8. Derived as follows: Fuel usage per ha x total No. of hectares.

9. Assumes that 1 l of gasoline contains 8179 kcal of energy. From Table C-1: Energy supplies and efficiency. From D. Pimentel, 1979. (For reference, see Footnote 6).

APPENDIX D

ENERGY CONVERSION TABLES

<u>Energy Resource</u>	<u>Unit</u>	<u>joules x 10⁶</u>
Crude Oil	Barrel	6,120
Petroleum Products		
LP Gas (propane/butane)	Barrel	4,230
Gasoline	Barrel	5,540
Kerosene	Barrel	5,980
Aviation Fuels	Barrel	5,540
Distillate (diesel, gas oil, heating oil, No. 2 oil)	Barrel	6,145
Residual (heavy oil, bunker- fuel, No. 5-6)	Barrel	6,630
Barrel of Oil Equivalent		6,120
Coal		
Bituminous		
U.S. Average	Metric Tons	27,900
Lignite		
U.S.	Metric Tons	16,300
Firewood	Metric Tons	14,000 ^a
Charcoal	Metric Tons	28,000 ^a
Bagasse	Metric Tons	7,000-11,000 ^a
Natural Gas	Cubic Meters	37,240
	Cubic Foot	1,087

MISCELLANEOUS CONVERSIONS

Volume	1 Barrel	= 42 gallons (U.S.)
	1 Gallon	= 3.785 liters
	1 Cubic Foot	= 28.32 liters
	1 m ³	= 35.31 cubic feet
	1 Barrel	= 159 liters
	1 MCF (10 ³ cu ft)	= 28.32M ³
Energy	1 kWh	= 3.3 million joules
	1 Btu	= 1055 joules
	1 kcal	= 4184 joules
Other	1 Barrel per Day	= 365 bbls (per year)
	1 MBDOE ^b	= 2.23 EJ (per year)

^aApproximate value or range.

^bMBDOE: million barrels per day oil equivalent, used frequently in energy statistics.