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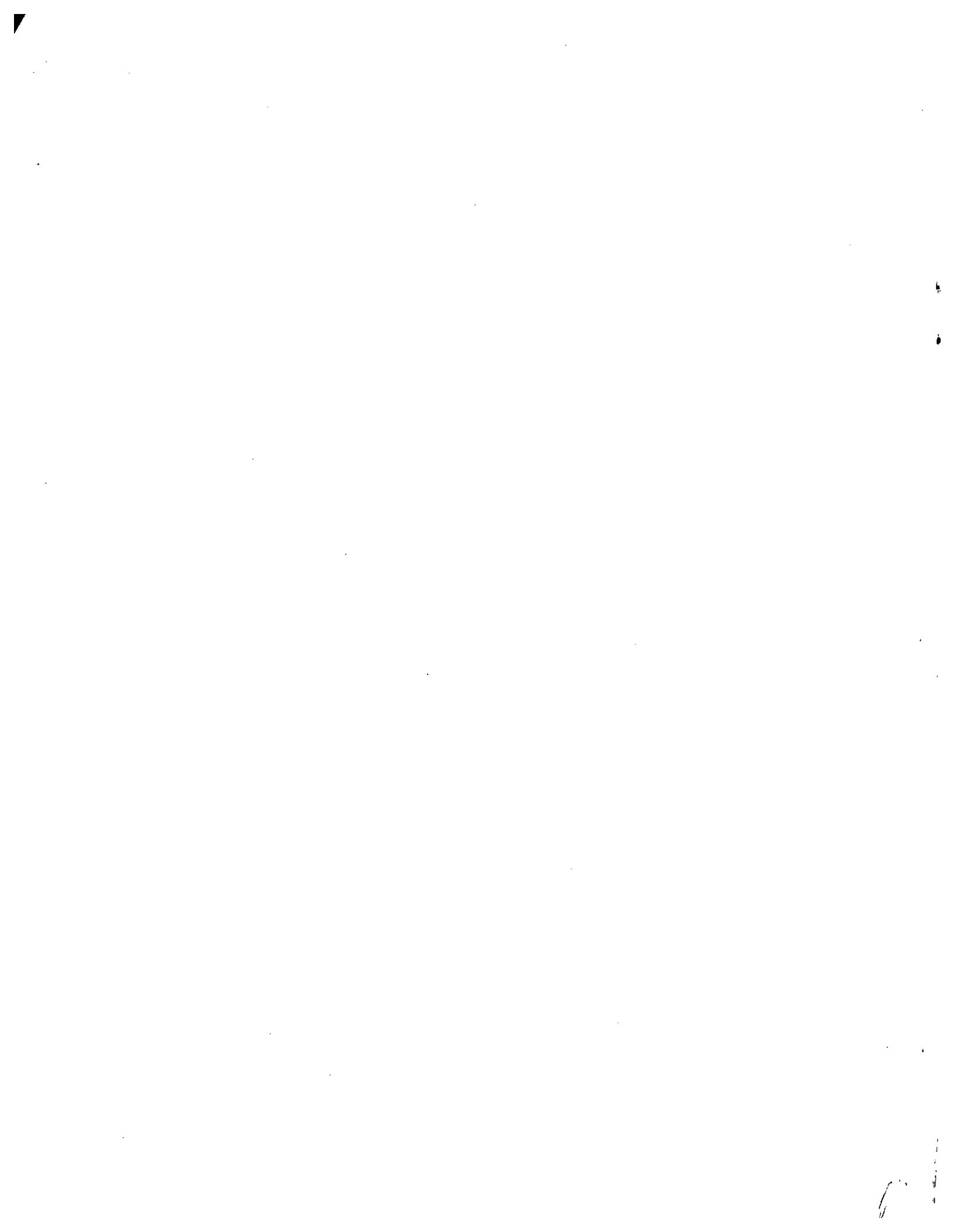
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ECONOMIC COMMISSION FOR LATIN AMERICA

Office for the Caribbean

PRELIMINARY DRAFT PAPER ON ENERGY RESOURCES
IN THE CDCC MEMBER COUNTRIES

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INTRODUCTION

As primary producers of agricultural commodities, the CDCC countries have to rely heavily on imports to satisfy most of their basic needs. One of the areas in which this fact is clearly evidenced is in the field of energy. Traditionally, energy demand had been met by relatively cheap petroleum imports since, for most countries, indigenous primary energy resources were not developed. However, since the Organization of Petroleum Exporting Countries (OPEC) raised crude oil prices so drastically, the once cheap source of primary energy is now quite expensive, resulting in severe balance of payments problems for the non-producers. This occurrence has brought to the forefront, the gross dependence of CDCC countries on liquid petroleum and consequently the urgency of utilizing alternative sources of energy.

As a first step, a concerted effort ought to be made to take a comprehensive inventory of all energy resources in the CDCC area. The next step in an energy programme would involve detailed research and investigation of the potential, including indications of feasibility and necessary follow-up actions. Following this, policies to determine priorities in an integrated development programme ought to be established. In this connection it may be pointed out that in the development of non-conventional energy resources, possibilities exist for small-scale, labour-intensive and rural installations which could facilitate development in other sectors. Development of non-conventional energy resources could therefore be linked for example, with the various attempts being made to reverse the urban drift, to alleviate unemployment and to boost agriculture.

It is hoped that this preliminary draft will give some insight into what exists and can probably be utilized, especially in the non-conventional area. Further mention must be made of the veritable dearth of quantitative data. Not enough resources, both human and economic are directed towards this extremely important aspect of development.

For the purposes of this paper, energy resources will be classified as conventional and non-conventional. Conventional energy resources refer to those traditional sources of energy - petroleum, natural gas and hydro-power, plus thermal electricity and petroleum refining facilities. Included also are charcoal and fuelwood, major traditional sources of energy in rural areas. Under the term non-conventional energy resources are some possible alternatives that are being considered, namely geothermal, solar, nuclear and biomass.

The geographical area under consideration refers to those countries of the Caribbean region that have membership status on the Caribbean Development and Cooperation Committee (CDCC), namely the Bahamas, Barbados, Cuba, Belize, the Dominican Republic, Grenada, Guyana, Haiti, Jamaica, Trinidad and Tobago and Dominica, and the West Indies Associated States of Antigua, Montserrat, St. Kitts-Nevis-Anguilla, St. Lucia and St. Vincent.

CONVENTIONAL ENERGY RESOURCES

Crude Petroleum

At present, only four CDCC area countries extract crude petroleum. These are Trinidad and Tobago, Cuba, Barbados and the Dominican Republic. Commercial oil production began in 1908 in the twin island state, thus making it one of the oldest producers in the hemisphere. Barbados started extraction only in the early 1970's and the Dominican Republic in the latter half of 1977.

Of these four petroleum producing countries, only Trinidad and Tobago is self-sufficient and Cuba and Barbados are able to satisfy about 3 and 30 per cent of their respective requirements currently. Information of this nature on the Dominican Republic is presently unavailable, it appears unlikely that they could have supplied their full requirements during 1978.

Conservative estimates of petroleum reserves are as follows:

Trinidad and Tobago	-	1 billion barrels
Barbados	-	1 million barrels
Dominican Republic	-	200 million barrels (Possible potential)

Cuba's reserves are unknown.

Assuming no new petroleum discoveries in Trinidad, it is calculated that present reserves of 1 billion barrels should last well into the 1990's while for Barbados it has been estimated that reserves will last for less than 10 years at a utilization rate of 350 barrels per day (bpd). Barbados' rate of extraction has been increased above 350 bpd. and there have been reports of an additional oil find in 1978.^{1/} Details on the extent of this oil find are not yet available.

^{1/} See Trinidad Guardian (newspaper) 11 July 1978, dated Bridgetown, Barbados.

In an effort to find petroleum deposits and so reduce the increasingly high energy bill, in the vicinity of some US\$5,000 million during 1977, several national studies have been commissioned by CDCC Governments. Studies have been undertaken in Jamaica, Haiti, Suriname, Grenada and Guyana with apparently promising results in most instances, so that for example, exploration contracts have been awarded in Suriname and Haiti. In Jamaica,^{2/} it was reported that an oil trace was discovered in the Windsor area of St. Ann and that a \$50 million exploration programme would be undertaken during the period 1978 to 1982.

Although the region can satisfy only a small portion of its crude petroleum needs, it nevertheless produces a substantial amount of petroleum-based products. Altogether in CDCC countries, there is a total of fourteen refineries with capacities ranging from 150,000 to 45,000,000 metric tons. In order of size of refinery capacity, the countries with refineries are the Bahamas, Trinidad, Cuba, Jamaica, the Dominican Republic, Antigua and Barbados. In addition, St. Lucia is due to get one with a capacity of approximately 250,000 barrels per day^{3/}, while Cuba is to get yet another in Cienfuegos which it is planned will have a total capacity of some six million tons annually, about double its present capacity.^{4/}

The main products of these refineries are motor gasolenes, kerosenes, jet fuel, fuel oils, lubricating oil and greases. The following table shows production and trade patterns of energy petroleum products over the three-year period, 1974 to 1976.

In any assessment of the natural resources of a country, the issue of ownership is of paramount importance since country and

^{2/} The Jamaica Daily Gleaner, February 3 1978.

^{3/} Carib Latin Energy Consultant (CLEC), October 1977, Vol. 1 No.10

^{4/} Actualidad Energética Lationamericana, junio 1977.
Organización Lationamericana de Energía. (OLADE).

TABLE 1

Production and Trade of Energy Petroleum Products
(Quantities in Million Metric Tons)

	Antigua	Bahamas	Barbados	Cuba	Dominican Republic	Jamaica	Trinidad
<u>Production</u>							
1974	0.325	9.691	0.133	5.105	0.877	1.589	18.124
1975	0.147	9.169	0.138	5.382	1.159	1.451	11.940
1976	...	7.788	0.140	5.645	1.403	1.336	15.223
<u>Imports</u>							
1974	0.103	1.400	0.257	1.793	1.140	1.110	0.097
1975	0.109	1.151	0.219	1.853	0.991	1.355	0.022
1976	0.216	0.889	0.148	1.870	0.753	1.449	0.091
<u>Exports</u>							
1974	0.133	10.543	0.012	...	-	0.057	15.188
1975	0.047	8.505	0.004	...	-	0.051	9.646
1976	...	7.082	0.002	...	-	0.032	13.204

... unavailable

- nil

Source: World Energy Supplies 1972-1976, United Nations New York, 1978

corporate interests are frequently at variance.^{5/} Petroleum in the Caribbean fits into the typical pattern of control by foreign multinational corporations. To date, with the exception of Cuba, no other country in the region has autonomous control over this sector of its economy. In Trinidad, for example, of the petroleum companies operating on the island, only one is owned by the State, and one in joint ownership of the Government and a transnational corporation, the others being subsidiaries of transnationals.

Generally, countries charge royalties, collect excise taxes, income and other taxes from companies in this field, but in some cases, special concessions have been granted to the companies. In an effort to get a greater share of the profits generated in the petroleum industry, tax rates are usually increased. The income tax applicable to the oil industry in Trinidad was drastically altered with the introduction of the Petroleum Taxes Act, 1974. This act provided for the separation of operations into crude oil production, refining and marketing for tax purposes^{6/} and the fixing of tax reference prices and a refinery throughput tax but it is alleged that companies are complaining that the tax is onerous.^{7/}

Natural Gas

Natural gas is a combustible gas that occurs in porous rock of the earth's crust and is found with or near accumulations of crude oil.^{8/} Natural gas may be found alone but more commonly it is found as a cap of gas in a reservoir trapped between liquid petroleum and a layer of impervious rock. Where the pressure is

^{5/} A case in point is the recently ordered Government of Trinidad and Tobago probe into the operations of Texaco Trinidad Ltd. because of allegations that the company is deliberately indulging in actions that are inimical to the country. (See Express (newspaper) of 3 January 1979 and The Sun of 2 January 1979.)

^{6/} Carib Latin Energy Consultant, June 1977, Vol.1 No.6

^{7/} See 5/

^{8/} Mc Graw-Hill Encyclopedia of Energy, Mc Graw-Hill Inc. USA.

great, natural gas may become mixed with the crude oil. Its main use is as a fuel but it is also used in repressuring wells as well as to produce liquid natural gas, natural gasoline and certain chemicals.

Natural gas is present in a variety of rock systems, therefore the energy-scarce CDCC area is not ruled out despite the general association of natural gas with crude petroleum. Natural gas is currently extracted commercially in Barbados, Cuba and Trinidad and Tobago. The largest known reserves are to be found in Trinidad and Tobago. As of 1 January 1978, the Natural gas reserves of Trinidad and Tobago were conservatively estimated at 12.04 trillion cubic feet, though it is felt that the figure could be as high as 21 trillion cubic feet. The total gas requirement to the year 2017 has been put at 8.6 trillion cubic feet, thereby leaving a surplus of some 4 trillion cubic feet over the conservative estimate.^{9/} In Barbados, at the end of 1976, current reserves were estimated at 933 million cubic feet,^{10/} though this figure is considered an underestimate. Information on the reserve position of Cuba is unavailable.

In view of the existence of geological formations deemed favourable for the presence of hydrocarbons and indeed the existence of crude oil in the Dominican Republic and possibly also in Suriname, there is the distinct possibility that the actual reserves of natural gas in the CDCC area will be much higher than indicated above.

In order of importance, the producers in the region are Trinidad and Tobago, Cuba and Barbados, as the following table indicates. In Barbados, utilization of natural gas represents about 2 per cent of total annual utilization of commercial energy; the figure for Trinidad and Tobago is nearly 50 per cent currently, but the share in Cuba's consumption is negligible.

^{9/} Statement in the House of Representatives on Gas Reserves and Liquefied Natural Gas. Minister of Petroleum and Mines, Port of Spain, Trinidad, October 15, 1978.

^{10/} Identification and Assessment of Conventional and Non-Conventional Energy Resources of Barbados; T. Fletcher, quoting the Twenty-fifth Annual Report of the Natural Gas Corporation of Barbados.

Table 2
Trends in Natural Gas Production
('000 teracalories)

Years	Trinidad and Tobago	Cuba	Barbados
1972	17.540	0.064	0.022
1973	16.874	0.135	0.028
1974	15.434	0.182	0.019
1975	14.084	0.158	0.019
1976	15.774	0.196	0.937
1977	15.775	0.200	0.035

Source: World Energy Supplies 1972-1976, United Nations, New York.

Natural gas is utilized mainly for household purposes in Barbados. As of 1976, sales to households accounted for more than 60 per cent of total sales. In Trinidad and Tobago, however, natural gas reserves have been expanding and the problem is to find use for this valuable resource. Presently, natural gas is used in areas such as electricity generation, in petroleum refining and in the petro-chemical industries. The necessary facilities are being established for using natural gas in heavy industry where energy requirements are large. When these industries are operating the excessive flaring or venting of natural gas should be considerably reduced. In Trinidad and Tobago, natural gas flared and vented without utilization exceeds 25 per cent compared with around 2 per cent in the United States.^{11/} It has been decided that those producing wells with unreasonably high quantities of associated gas will be closed off until more effective use can be made of this depleting resource.

In Barbados, the sale of natural gas is in the hands of a public utility, reporting annually to the Government. This Corporation apparently purchases gas from the multinational corporation

^{11/} Mc Graw-Hill Encyclopedia of Energy, Mc Graw-Hill Inc. USA

which does the exploration and extraction.

Natural gas is sold directly by the producers to the utilizing firms in Trinidad and Tobago. Most of the producers are foreign multinationals operating under agreement with the Government. One such agreement ensures the provision of gas to the sole electric public utility. Generally the natural gas industry comes under the regulatory ambit of the Ministry of Petroleum and Mines.

Data are not available on the uses of natural gas nor on the organization of production and distribution enterprises.

Hydro-electric Power

Hydro-electricity refers to power generated through the use of flowing water. Typically, water is stored in dams and released as desired to turn turbines to which electric generators are attached.^{12/} Hydro-power is the oldest known mechanical power source and has a lot of properties which make it very suitable for use in developing countries in the current world context. It is low in cost, high in efficiency and is the least polluting of the conventional energy types; additionally, it has the capacity to be easily adapted to non-power uses such as flood control, irrigation, water supply, etc.

Not all of the CDCC area have the topography and climate suitable to hydro-electric projects because most are islands, some relatively small with a few small rivers and in some cases there are no rivers. Examples of these are some of the Bahama Islands, Antigua, Barbados and St. Kitts. It is not surprising therefore, that at present, hydro-power is utilized commercially only in Cuba, Dominica, the Dominican Republic, Guyana, Haiti, Jamaica, St. Vincent and Suriname. Up to 1976, installed hydro-electric power capacity in the CDCC area totalled around 390,000 kilowatts of which Suriname accounted for over 47 per cent and St. Vincent less than one per cent. Generation varies from 10 million to 1,176 million kilowatt hours.^{13/}

^{12/} Mc Graw-Hill Encyclopedia of Energy, Mc Graw-Hill Inc. USA.

^{13/} World Energy Supplies, 1972-1976, United Nations, New York.

The steep rise in petroleum prices of 1974 induced countries to give further consideration to utilization of hydro-power. Haiti, for example has increased hydro-power capacity by 50 per cent during the 1970's while hydro-power capacity in the Dominican Republic during 1976 was six times as large as in 1972. Hydro potential appears most promising in Guyana and Suriname and detailed studies have been undertaken in order to effectively use this energy source. In Guyana, the hydro-power potential has been estimated at over 7,000 megawatts.^{14/} There is already in progress, a project for the development of 1,000 megawatts of hydro-power capacity in the Mazaruni area of Guyana by the mid 1980's. Suriname has plans also for another hydro-power project which will supply an additional 1,000 megawatts of power.

In Haiti and Jamaica, it is estimated that there is additional hydro-power potential of some 80 and 120 megawatts respectively,^{15/} while in Grenada, although there is no knowledge that hydrological surveys have been undertaken, it is reasonably assumed that some hydro-electric potential does exist.

In Belize, hydro-power potential is believed to exist on the Rivers Macal and On, though the capacity is yet to be determined. A pilot project is however, being prepared for the Rio On site. Dominica appears also to possess potential for generating additional hydro-power, but project evaluations are still to be undertaken.

While urbanization is fairly developed in the CDCC area, there are still clusters of rural population without electricity. Rural electrification schemes relying on large power grids based on transmitting electricity generated with the use of petroleum over long distances may prove far too costly in 1979. Attention needs to

^{14/} A study by the Montreal Engineering Company Limited under a project financed by the United Nations Development Programme.

^{15/} S. Satcunanathan; Identification and Assessment of Conventional and Non-conventional Energy Resources of Haiti, May 1977 and Emergency Production Plan, Jamaica, 1977-1978

be turned towards small scale hydro-generation in rural areas whether or not linked with thermal power grids or with irrigation and other water projects.

Thermal Electricity

It would appear that of all forms of energy, thermal electricity accounts for the largest share of final consumption in the CDCC area, which is another way of expressing the dependence of the region on petroleum products. Very few countries utilize other sources for electricity generation. The table below gives data by country on installed thermal capacity and generation for the most recent available year.

There is substantial variation in the utilization rate of thermal electricity from country to country ^{16/} during any given year. Cuba, Belize, the Dominican Republic and Jamaica have tended to have the highest rates in recent years and some of the smaller countries show the lowest rates. Many factors account for the variation: industrial disputes, breakdown of equipment, stoppage for maintenance, etc., however this utilization rate can be considered in some ways as a measure of efficiency. Utilization ratios in the CDCC area compare favourably with similar ratios for the United States, Canada, Brazil and Venezuela, where the figures averaged 3980, 3060, 2000 and 4100 respectively between 1972 and 1976. However, the CDCC area ratios are much less than in the efficiency-conscious countries of Japan and Northern Europe. (Most of these are petroleum deficient countries!) The total average utilization rate of the data in the table below is only 39 per cent. A 50 per cent utilization rate on the basis of 1976 capacity would give a ratio of closer to 4400 which is nearer the levels of the better European performers.

With increasing economic activities in the region, it is envisaged that electricity production will rise substantially over

^{16/} Utilization rates for hydro-electricity are considerably higher.

the next few years, though the extent of expansion will most certainly depend largely on the rising cost of fuel. Definite plans for the expansion of generating capacity have been formulated for Trinidad and Tobago, Cuba, Guyana, Barbados, Antigua and some of the CDCC territories. Part of the expansion in output could be achieved by replacement of outmoded and depreciated equipment and improved maintenance practices.

Table 3
Selected Data on Thermal Electricity

Country	Year	Installed Capacity 000 kW	Generation		Total	Utilization Ratio ^{1/}
			Petroleum Products Mill kWh	Natural Gas		
Jamaica ^{2/}	1977	487	1400	-	1400	2875
Barbados	1977	97	264	-	264	2722
Trinidad & Tobago	1977	493	-	1431	1431	2903
Bahamas ^{3/}	1976	255	600	-	600	2353
Grenada ^{3/}	1976	7	28	-	28	4000
Antigua ^{3/}	1976	22	47	-	47	2136
Belize ^{3/}	1976	12	43	-	43	3583
Cuba	1976	1661 ^{3/}	7145	4302
Dominica	1976	3	2	-	2	667
Dominican Republic	1976	647 ^{3/}	2515	3887
Guyana	1976	180 ^{3/}	398	-	398	2211
Haiti	1976	42 ^{3/}	50	-	50	1190
Montserrat	1976	4 ^{3/}	9	-	9	2250
St. Kitts-Nevis-Anguilla ^{3/}	1976	13	23	-	23	1769
St. Lucia	1976	14 ^{3/}	45	-	45	3214
St. Vincent ^{3/}	1976	7	7	-	7	1000
Suriname	1976	181	159	-	159	878

^{1/} Figures are kWh per unit of installed capacity

^{2/} Public only, industrial not available

^{3/} United Nations estimate.

... not available

- nil

Source: World Energy Supplies, 1972-1976 and data supplied CEPAL

Fuelwood and Charcoal

Forest resources are one of the most widely available of energy resources in the CDCC countries; consequently, the use of charcoal and fuelwood has played a substantial role, traditionally, in the generation of energy in the area. However, quantitative data on production is lacking for most of the countries. Charcoal and fuelwood have been used mainly for cooking, though with increased industrialization and the advent of modern cooking equipment, cheap petroleum and reduced forest areas, their use has been declining in the region as a whole.

Data on land area classified as forested in selected CDCC countries are included in the table below. It will be noted that Guyana and Suriname have the largest forested areas and that several countries also have relatively large "forested" areas, compared to their total land area. The problem almost universally throughout the region, until recently, has been one of indiscriminate cutting of trees for fuel and non-fuel uses combined with a lack of re-afforestation efforts so that actual yields from forests would be lower than if the areas were well wooded.

Using relationships derived from one source^{17/} operating at 35 per cent average efficiency^{18/} thermal electricity plants fired by wood up to a capacity of 100 MW could potentially be supported by the forests of a country as small as Dominica. The potential for the larger countries is obviously greater. Potential should be stressed here since a number of problems and qualifications must be made to the data. Problems would include the logistics of logging, transportation etc., which have affected the timber industry in some countries. The condition of forests may be such that the total area gives a misleading picture of the number of trees and the present often lucrative alternative uses of wood

^{17/} Report on Identification and Assessment of Conventional and Non-conventional Energy Resources of Haiti; (Mimeo), May 1977, by S. Satcunanathan.

^{18/} For the period 1972-1976, thermal electric plants in the CDCC area average 39 per cent operating efficiency.

also affect the actual quantity of timber that would be available. For these reasons, the table should be used with great caution.

Table 4
Energy Potential from Forestry Bio-mass
Compared with Electric Generating Capacity - 1976
Selected CDCC Countries

Country	Forestry Land Area sq km	Energy Potential MW	Present Electricity Generating Capacity MW	Ratio Col 2/Col 3
	(1)	(2)	(3)	(4)
Jamaica	4,920	1,800	685	2.6
Dominican Republic	11,040	3,900	743	5.2
Cuba	12,300	4,400	1,705	2.6
Guyana	181,900	65,000	180	361.1
Belize	10,120	3,600	12	300.0
Suriname	143,500	51,300	361	142.1
Bahamas	3,240	1,200	255	4.7
Trinidad & Tobago	2,260	800	454	1.8
Haiti	2,000	700	89	7.9
Dominica	350	100	6	16.7

Source: FAO Production Yearbook, 1977; Volume 31 (for forest area)

The rapid rise in petroleum prices and the general absence (region-wise) of other large-scale energy resources indicate that serious consideration be given to utilizing renewable forest resources as a source of energy. The dry bio-mass of forests can be used directly as fuel for producing thermal energy or to produce methane.^{19/}

Certain definitive actions are indicated before systematic utilization of forest resources for energy could begin. Among these

^{19/} Methane is a combustible gas when mixed with air and is formed by the anaerobic decomposition of vegetable matter and is a major constituent of natural gas and can therefore be used as a fuel. (Mc Graw-Hill Encyclopedia of Energy, Mc Graw-Hill Inc. USA.)

preliminary actions are the following: -

- (a) A complete survey of forested areas, where such an inventory does not now exist, to determine extent, geographical location, general condition of trees, quantity of which varieties, etc. It will be necessary to update the records annually.
- (b) Institution of conservation and re-afforestation practices urgently, including controlled cutting of trees. Data on Haiti indicate the urgency. Forest and woodland areas were put at an average of 340,000 hectares in 1961-1965, but by 1975 the total was estimated at only 235,000 hectares and is estimated to be completely exhausted by the year 2000 if no conservation measures are taken.^{20/}
- (c) A detailed study of the relative advantage of wood in different uses, for example, as lumber, pulp and paper, etc. There may not be much choice in some cases since energy is indispensable to modern living. However, it should be borne in mind that variety of trees and their condition are important in some non-energy uses of wood. Thus, selective planting of species can reduce the problem of competing uses.

^{20/} U.S. A.I.D., Agricultural Development in Haiti, Washington D.C., 1978, quoting FAO advisers Raeder-Roitsch and Zenny from a 1975 study.

NON-CONVENTIONAL ENERGY RESOURCES

Solar Energy

The sun holds the greatest potential in the region as a possible source of energy, because of the abundance of daily sunshine most of the year. Considerable savings in foreign exchange could be realized by tapping some of the sun's vast, non-depleting reserves of energy. It is estimated that the intensity of solar radiation in the latitudes of the CDCC area averages about 6 kWh/m² day on clear days with an annual average of about 5 kWh/m² day.^{21/}

However, before this prolific energy source can be optimally utilized, there must be adequate quantitative data on insolation levels at various locations in the respective islands. At present, such data are lacking for most islands. It would appear that a wider network of measuring locations is necessary in all countries for a fuller evaluation of the potential.

Drying of crops such as coffee, cocoa beans and spices has long been practised in the region. It is necessary however, to optimize the use of solar radiation. To this end, experiments have been conducted, using locally designed dryers.

Solar stills and water heaters have already been in use though on a limited scale. In the Caribbean, two solar stills have been built by the Brace Research Institute of Mc Gill University at Isle de Gonave, Haiti and Petit St. Vincent in the Grenadines. These stills have been successfully used to provide potable water to small rural communities by a process of solar distillation. Stills are one of the simplest and most effective applications of solar energy and could meet the potable water needs of isolated, rural communities.

^{21/} S. Satcunanathan; Non-conventional Energy Resources for the West Indies. Second Caribbean Seminar on Science and Technology, Policy and Planning, Port of Spain, Trinidad, 12-16 January 1976.

This is especially important in a geographic region where there are a substantial number of rural population concentrations and acute water problems. In another area of present use, solar water heaters can be manufactured locally as is the case in Jamaica and Barbados where they are mainly for household use. It is estimated that if these water heaters could be used for the tourist industry in both these countries where tourism plays such an important role, substantial inroads could be made in helping to reduce that sector's consumption of petroleum-based energy. Undoubtedly, a similar claim could be made for other countries with large tourist trade.

As the prospects for utilizing solar energy appear promising and since some of the equipment and apparatus can be manufactured within the region, it would be advisable that this area be given priority consideration. Possible areas for the immediate use of solar energy via the thermal process where moderate temperatures of up to 150°C are required, are water heating, desalination, drying of agricultural and marine produce, food processing and small vapour power plants for irrigation and rural electrification.^{22/} The costs of bringing into operation some of these various activities need not be very high; for example, the solar still in Haiti, soon after completion, was producing an average of 1,250 litres of water from brackish and sea water and the overall costs totalled about \$17,000.^{23/}

Geothermal Energy

Geothermal energy is the use of steam or hot water from natural sources as a power source, used mainly for generation of electricity. With increasing depth below the earth's surface,

^{22/} S. Satcunanathan, A Development Strategy for the Utilization of Solar Energy in the West Indies, Seminar on Non-conventional Energy Sources, Port of Spain, Trinidad, 15-19 November 1976.

^{23/} A Handbook of Appropriate Technology, Canadian Hunger Foundation, Ottawa, Canada, April 1976.

the temperature increases about 15°C per kilometer. However, in areas where there has been volcanic activity, the rate of temperature increase may be much greater. Natural geothermal power is normally limited to those parts of the world where volcanic activity are prevalent and occurs as geysers or other emissions of water or steam. There are however, underground reservoirs of hot water which can be reached by deep drilling.

In the CDCC region, little work has been done in this field, possibly due to the fact that geothermal potential is not considered great for the region as a whole, because there is little volcanic activity and relatively few hot springs.

Within the CDCC area, Dominica, Montserrat, St. Lucia, Haiti, Jamaica and Grenada are considered to have the greatest potential because of the existence of hot springs. Preliminary analysis of the geothermal source of power at Soufrière, St. Lucia, indicated a potential energy capacity of 10,000 kW.^{24/} In St. Lucia, the exploratory drilling can be described as a moderate success so far and present plans call for the installation of a small steam-driven turbine. Financial constraints are inhibiting further investigation. Information about recent survey activity in Dominica and Montserrat is unavailable. It appears that the natural geothermal manifestation in Jamaica is insufficient for power generation, while for Haiti and Grenada, it will be necessary to determine the origin of the hot springs, i.e., whether geochemical or geothermal, before any exploratory drilling is effected. Of course, deep drilling could increase the possibilities. A study of the possibility of geothermal electricity generation is presently being undertaken in the Dominican Republic.^{25/}

Since geothermal energy is the most inexpensive source of electric power generation,^{26/} this source of energy should be thoroughly investigated wherever there are positive indications.

^{24/} Inventory of the Resources of the CARICOM Region, UN CRIAT, December 1975, a report by Ms. Ione Marshall.

^{25/} Caribbean Basin Economic Survey, Federal Reserve Bank of Atlanta, September/October 1978, Volume 4, Number 5.

^{26/} Mc Graw-Hill Encyclopedia of Energy; Mc Graw-Hill Inc USA

Nuclear Energy

The basic fuels for nuclear reactors are uranium ore (238) which occurs naturally and plutonium (239) and uranium (233), both of which are by-products of nuclear power reactors. Effectively therefore, consideration of energy resources is limited to uranium ores. So far, there is little hard evidence of the availability of uranium ore in the CDCC area.

Surveys have been carried out in the Pakoraima Mountain Range of Guyana for deposits of uranium and it would appear that results have been favourable, though the quality and extent of these deposits are not yet known.^{27/} However, according to latest reports, exploitation is to begin soon.^{28/}

In Jamaica, extensive surveys were conducted in the 1950's for uranium ores with negative results. Several mineral springs have been tested for the existence of radioactivity, but the tests unfortunately did not indicate the presence of any significant radioactive deposits.

It means therefore, that more systematic geological surveys remain to be done. Furthermore, countries may need to consider the possibility of purchasing nuclear power plants. In both instances, there will have to be dependence on foreign technology but the possibility of discovery and the high cost of conventional energy justify at least investigations in suitable locations. Capital will be a problem in either case, but more so for the purchase of plants as only few countries, notably Trinidad and Tobago, can afford a nuclear plant at present. It may be noted that Cuba has plans for opening its first nuclear energy plant and with this in mind, an electrical nuclear institute was scheduled to begin operations in 1978 for the training of intermediate level

^{27/} Identification and Assessment of Conventional and Non-conventional Energy Resources of Guyana; T. Fletcher.

^{28/} Carib-Latin Energy Consultant (CLEC) February 1978.

and other personnel.^{29/}

In the other CDCC countries, very little is known of the probable plans for the utilization of this form of energy, though it has been reported that the Government of Trinidad and Tobago has signed with the French Government, a technical-economic agreement which includes the development of nuclear power.^{30/}

Beside the difficulty of funding the purchase of nuclear materials, there would be problems of security and international implications because of the possibility of conversion to non-peaceful uses. It would appear that nuclear power will not be a priority at the present time for the CDCC countries.

Agricultural Wastes

Bagasse

Bagasse, the fibrous residue after the juice is extracted from the sugar-cane has long been used as fuel for steam-powered electricity on sugar plantations.

Sugar-cane is grown in all the countries of the CDCC and in relatively large quantities in the ten countries included in the Table below. One researcher^{31/} indicates that sugar factories in Haiti are able to satisfy all their energy requirements from bagasse with a surplus which is sold to the electric utility company. Considerable use is made of bagasse as fuel in some of the other countries as well.

The energy content of dry bagasse (i.e., on a moisture free basis) is put at 5.15 kWh/kg.^{32/} The results of calculations shown in the Table indicate tremendous potential based on utilizing

^{29/} Carib-Latin Energy Consultant (CLEC), September 1977; Volume 1, Number 9

^{30/} Carib-Latin Energy Consultant (CLEC), July 1978; Vol 2, No.7

^{31/} Mac Berthouex P and Rudd-Dale F; Strategy of Pollution Control (Pg. 135). John Wiley & Sons, New York.

^{32/} See ^{15/}

all the available bagasse. Except for Jamaica and Trinidad and Tobago, the electricity potential from bagasse is several times larger than the current generation of electricity. This fact clearly demonstrates that in any country where there is surplus bagasse, serious investigations of its use as a fuel should be undertaken. In fact, it is not too far-fetched to suggest, on the basis of the foregoing, that perhaps growing of sugar-cane for its use as fuel should be considered, given the 1979 prices of petroleum.

Table 5

Estimates of Potential Energy Yield
from Bagasse compared with Total
Electricity Generation
1976

Country	Estimated Bagasse Yield ('000 mt)	Energy Potential (million kWh)	Total Electricity Generation (million kWh)
Barbados	138	762.2	228
Cuba	7,800	40,170.0	7,198
Dominican Republic	1,640	8,446.0	2,690
Guyana	615	3,167.3	398
Haiti	417	2,147.6	209
Jamaica	544	2,801.6	2,378
St. Kitts-Nevis-Anguilla	48	247.2	23
Trinidad & Tobago	348	1,792.2	1,367

Source: World Energy Supplies, United Nations, New York and data supplied CEPAL.

However, there are some constraints to the continued utilization of bagasse for energy requirements: -

- 1) sugar production has declined substantially in some countries;
- 2) by burning the bagasse, the soil is deprived of valuable fertilizing materials;

- 3) the alternative uses to which bagasse can be put, that is, in the manufacturing of fibreboard, animal feed and paper, etc.

The use of bagasse for energy depends on some factors or combination of factors listed above.

Rice Chaff

Rice is another major crop of the CDCC area. In 1976, production in the eight major producing countries amounted to over 1.2 million metric tons as shown in the table below. Since that time, production has increased in several countries. The potential energy yield, utilizing a ratio of 0.25 chaff to paddy and 12.77 MJ/kg are also shown in the table. While not as impressive as the potential yield from bagasse, nevertheless, in some cases (especially Haiti and Guyana, but also in Belize and Suriname) the possible maximum energy from rice chaff would boost present electricity production quite considerably.

Table 6

Rice (Paddy) Production and Potential Energy Yields - 1976

Country	Rice Production ('000 mt)	Estimated Chaff (mt)	Energy Potential (million kWh)	Total Electricity Generation (million kWh)
Belize	6.3	1,575	6	43
Cuba	451.0	112,750	400	7,198
Dominican Republic	286.0	71,500	254	2,690
Guyana	172.9	43,225	153	398
Haiti	131.0	32,750	116	209
Jamaica	2.0	500	2	2,378
Suriname	172.5	43,125	153	1,335
Trinidad & Tobago	20.0	5,000	18	1,367

Source: FAO Production Yearbook 1976 and data supplied CEPAL.

Energy from rice chaff would perhaps be most effective if utilized directly on farms, in mills, etc. The feasibility would however, have to be investigated in each case. It may be noted that as more rice is grown as part of the self-sufficiency in food programmes being espoused in several CDCC countries, more chaff will become available. As in the case of bagasse and other agricultural commodities, rice husks particularly, have competing uses (animal feed). Choices need to be made but the energy need is compelling.

Other Agricultural Wastes

The CDCC area consists basically of agricultural countries; consequently in addition to timber, sugar and rice there are other products, the waste of which could be utilized in producing energy. Among these products are maize (corn), sisal, bananas, coffee, cocoa and coconuts. While much of the waste of these are allowed to rot and become a source of natural fertilizer, some could be utilized as energy. (Coconut shells have been used to fire ovens for producing copra from coconuts.) Serious efforts need to be undertaken now to investigate the possibility of utilizing these various crop wastes in producing energy.

Biogas

Human and Animal Waste

By allowing manure and other organic wastes to decompose in a sealed tank called a digester, due to the action of bacteria, biogas is produced. Biogas is essentially a mixture of methane and carbon dioxide with traces of nitrogen, hydrogen and hydrogen sulfide. About 50-70 per cent of biogas contains methane, the same substance of which about 95 per cent of natural gas is composed. Biogas can therefore be used for the same purposes as natural gas. Additionally, the residue left in the digester after the cessation of gas production makes a good fertilizer.

Human and animal wastes are therefore an important source of potential energy. Where there are existing systems for the disposal of sewerage in the region, the potential for gas generation can be reasonably estimated.

Data on selected cities in the CDCC area are given in the table below. The figures are for 1970 and relate to the greater city areas which may not all be linked at present to one central sewerage system. However, since 1970, urban populations have increased in several countries of the region so that the potential energy generation in 1978 can be said to be higher than the figures shown in the table. With these limitations in mind, it will be seen that in some cases, the contribution from one major city only is sizeable compared to 1976 total electricity generation, in the case of Haiti 18 per cent and in Guyana, 3 per cent. Obviously, if central sewer systems exist in all major cities, the real potential would be considerably greater.

Not enough current data are available to make a close assessment of the energy potential from animal waste. It should be noted however, that estimates for the CDCC area show the average annual populations of cattle as 10.5 million, pigs 4.4 million, sheep 0.7 million, goats 1.9 million and poultry 47.7 million between 1972 and 1974^{33/}. Another source^{34/} estimates that wastes from 1000 poultry broilers "will be capable of producing about 10m³ of methane gas per day ... an energy equivalent of 100 kWh per day." If one assumes 30 million broilers, the potential energy equivalent of the methane gas that could be produced would be 3 million kWh per day which is quite considerable. There are also reports^{35/} of at least one unit generating methane gas from animal wastes in Jamaica.

^{33/} Agricultural Statistics of the Caribbean Countries, UN ECLA Office for the Caribbean, August 1976, (ECLA/POS 76/5)

^{34/} See 17/

^{35/} See 17/ and Mac Berthouex, P. and Rudd-Dale, F; Strategy of Pollution Control; John Wiley and Sons, New York, London.

Table 7

Crude Estimates of Possible Energy Potential of
Human Wastes in Selected Countries

Country	City	Population	Estimated Annual Biogas Production '000 m ³	Million kWh
Cuba	Havana	1,751,216	20,071	134.7
Dominican Republic	Santo Domingo Santiago de los Caballeros	817,645 245,165	12,181	81.7
Haiti	Port au Prince	493,932(1971)	5,661	38.0
Guyana	Georgetown	164,039	1,880	12.6
Jamaica	Kingston	475,548	5,450	36.6
Trinidad & Tobago	Port of Spain	67,867	778	5.2

Population figures are for 1970 with the exception of Haiti.

Source: Demographic Yearbook 1975 United Nations, New York, 1976. This source refers only to the population figures.

Municipal Wastes

With the continued urbanization of many of the CDCC countries, waste disposal is becoming a bigger problem every year. It may be possible to make a substantial contribution to alleviating both the water problem and the energy problem by converting waste to some beneficial use.

One source suggests a reasonable figure of refuse collection per head per day of 1.2 kg, having a calorific value of 7 kJ.^{36/} Using these assumptions and the further assumption that about 40 per cent of the population live in urban centres or towns where mass collection of wastes is the practice (or at least is feasible)

^{36/} See ^{17/}

yield the results shown in the table below.

The potential here appears quite significant, however, caution is indicated in any interpretation. It will be noted that the potential is higher than present (1976) electricity generation in Haiti and Suriname and over 60 per cent of the total in Cuba, the Dominican Republic and Guyana. The populations of some of these countries are still fairly dispersed so that centralized collection of garbage for 40 per cent of the population may be a high figure, as may also be the case with the 1.2 kg waste disposal per person per day, bearing in mind also the low age levels of the population. It is also not known if human waste is included in the 1.2 kg per person per day figure used in the calculations. The material composition of the waste may also be low in combustible material. Despite all these reservations, the indications are that the potential is quite large and serious consideration ought to be given to retrieval and use of the energy constituent of municipal waste.

Table 8
Estimated Energy Potential from Municipal Wastes
in Selected CDCC Countries

Country	Estimated Annual Municipal Wastes (kgms)	Total Calorific Value (million kWh)	Total Electricity Generation (million kWh)
Barbados	44,500,800	86	228
Cuba	2,489,767,200	4,839	7,198
Dominican Republic	872,145,600	1,695	2,690
Guyana	144,890,400	281	390
Haiti	832,024,800	1,617	209
Jamaica	365,292,000	710	2,378
Suriname	78,489,600	152	23
Trinidad and Tobago	192,369,600	374	1,367

