CEER – W-112

THE ENERGY ALTERNATIVES FOR THE CARIBBEAN

by

Dr. Juan A. Bonnet, Jr., Director

Presented at Seminar on

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

BRIDGETOWN, BARBADOS

DECEMBER 7, 1981

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO U.S. DEPARTMENT OF ENERGY

THE ENERGY ALTERNATIVES FOR THE CARIBBEAN

by

Dr. Juan A. Bonnet, Jr., Director

Presented at Seminar on

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

BRIDGETOWN, BARBADOS

DECEMBER 7, 1981

THE ENERGY ALTERNATIVES FOR THE CARIBBEAN

By

Dr. Juan A. Bonnet, Jr., Director

Center for Energy and Environment Research

University of Puerto Rico

Presented at

SEMINAR ON

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

Bridgetown, Barbados

December 7, 1981

--------()--------

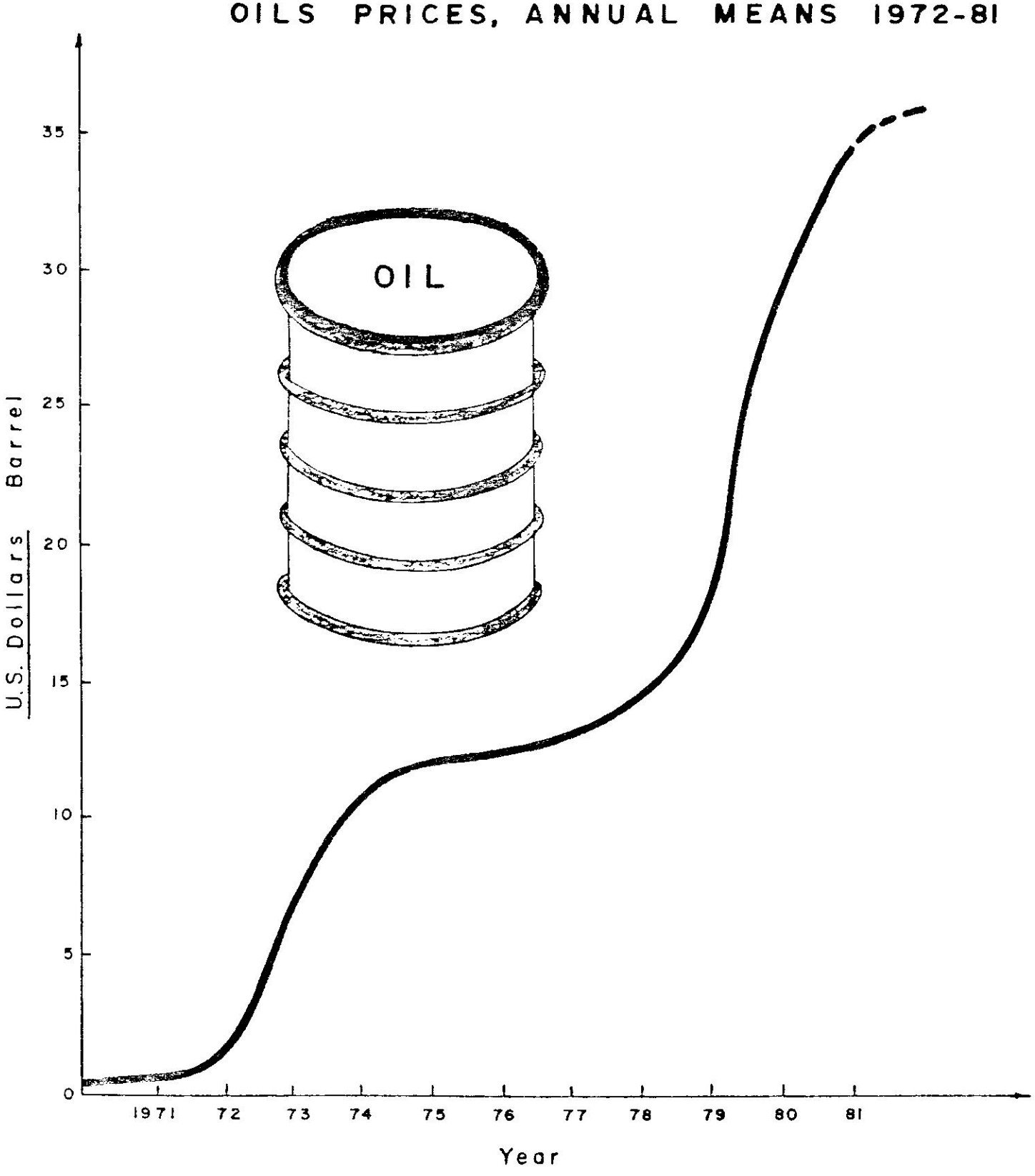
INTRODUCTION

For the developing countries there was some good news from Geneva at the end of November. The Organization of Petroleum Exporting Countries (OPEC) agreed to increase world oil prices to US$34 a barrel, but it also decided to freeze this basic price until December 1982, thus protecting poorer countries from unexpected and unmanageable increases[1].

Yet, unless long range steps are taken soon, the OPEC action may not be enough[2]. Nearly 100 developing countries depend on oil to meet more than sixty percent of their energy needs. Most of them import four-fifths of their total oil requirements. The price of oil, in inflation-adjusted terms, has quintupled over the past decade (See figure 1), and many analysts predict price increases of three percent annually. This means the poor countries are now spending $50 billion a year to pay for imported oil and they could be paying $110 billion a year by 1990.

To offset this economic drain, many countries are turning to the most readily available alternative supply. Forty percent of the developing world's timber reserves may literally go up in

Figure 1


OILS PRICES, ANNUAL MEANS 1972-81
OIL
U.S. Dollars Barrel
0
5
10
15
20
25
30
35
1971
72
73
74
75
76
77
78
79
80
81
Year

smoke, as households and small industry substitute firewood for oil. In a number of Caribbean countries exploitation of wood resources is not in equilibrium with regeneration rates. Wood and charcoal meet a large part of Haiti's energy requirements and in a lesser degree of countries with forest reserves such as Belize, Dominican Republic, Grenada, Guyana and St. Lucia.

While developing countries contain two-thirds of the world's population, they account for only one-seventh of world energy's production. The success that developing countries achieve in reducing their dependence on imported energy will determine, in large measure, the degree of flexibility they will have in managing their economies in the future. Since the Arab oil embargo of 1974, the debt of developing countries has more than quadrupled to $425 billion, causing more of their income to go for debt service at continuously increasing rates of interest.

The World Bank estimates that up to 30 percent of the developing world's energy needs could be eliminated around 1990 by maximizing conservation efforts and by increasing energy production from fuel sources such as oil, gas, coal, hydropower and renewables. It has outlined ways of reducing those energy needs by 15 percent without sacrificing economic growth during the coming decade.

During this year there has been an increase of discussion about energy[2]. Last November, south and north countries, talked about energy at the Cancum, Mexico Summit Meeting. Before this in August there were many discussions about renewable energy at the United Nations Conference on New and Renewable Sources of Energy in Nairobi[3]. For months there have been discussions about a World Bank proposal to set up a separate energy affiliate within the bank, but up to now no concrete agreements have been reached.

On the other hand, according to the Interamerican Development Bank (IADB) crude oil production is growing faster in Latin America than in any other region of the world[4]. In its 1980 report on economic and social progress in Latin America, it stated

that oil production in Latin America expanded by nearly 10 percent and the region's share of the world oil markedly rose from 7.7 percent in 1977 to 9.8 percent in 1980. At year end, the total oil output of the region reached to 2.123 billion barrels, exceeding consumption by about 700 million barrels an increase of 100 million barrels over 1979. The rate of growth in production was the highest since 1973, and compares favorably with the 8.5 percent expansion of 1979. Combined production of Mexico and Venezuela accounted for nearly 75 percent of the region's crude oil production from 1975 to 1980, although Venezuela's share fell from 53 percent in 1975 to 37 percent in 1980, while Mexico's production rose from 18 percent of the region's output to 37 percent during the same period. Concerning oil exportation, "the single most important event during the past five years has been Mexico's contribution to the region's increased sales of crude to external markets," the IADB report said. Mexican oil reports increases of 114 percent in 1977, 79 percent in 1978, 47 percent in 1979 and 55 percent in 1980 when they totaled about 303 million barrel. Production also expanded in Argentina, Brazil, Chile, Peru and Guatemala, but it declined in Bolivia, and Trinidad and Tobago. In Venezuela, production declined by almost 8 percent as a result of conservation measures enforced by the Government[4].

The Mexican and Venezuela governments are implementing an important oil purchasing financing agreement for the Caribbean. The New York Times editorialized recently that the Caribbean is being rediscovered again[5]. The agreement covers up to 80,000 barrels for each country. According to the agreement, a sum equivalent to 30 percent of the value of the crude purchased by the recipient country will be financed by the Venezuelan Investment Fund and the Central Bank of Mexico. The loan will be given for five years at a 4 percent rate of interest. If however money is invested in development projects, preferably in energy, the loan will be extended for twenty years and the rate of interest will be lowered to 2 percent.

The World Bank has also called for an international research program to improve and broaden the use of renewable energy technologies in developing countries[4]. The Bank, in a recent report, "Mobilizing Renewable Energy Technology in Developing Countries: Strengthening Local Capabilities and Research," particularly emphasizes the role of biomass in the developing countries. Although in some countries "up to 90 percent of energy consumption comes from biomass," the report concludes that "present research efforts to improve biomass production are inadequate to begin to realize the enormous potential of this resource for the longer term. A well designed and executed biomass research program would improve the productivity of conventional biomass materials such as sugarcane, cassava, and sweet sorghum and identify species that are potentially more productive. The research should be conducted in forestry and agricultural laboratories located in developing countries".

The second part of the World Bank proposal focuses on the development of technologies for the production of energy from direct solar, wind, small hydro and biomass resources. Because a great deal of research to improve these technologies is already being done in the developed and in the more advanced developing countries, the program would be directed at assisting less developed countries (LDCs) to assess and adapt new technologies for their own national programs. The aim of such an international program would be to develop reliable data on renewable energy technology performance, evaluate experiences in different countries with the adoption of the technologies, and make global assessments of future technological developments and their implications for developing countries.

The Latin America Plan for Action for the United Nations Conference on New and Renewable Sources of Energy recommended that priority be given to the following:[6]

1. Regional Basic Support
   a. energy planning

b. information and dissemination

c. training

2. Integral Regional Development

a. hydroelectric

b. firewood and charcoal

c. liquid fuel production

d. solar energy

e. vegetable residues

f. geothermal energy

g. biogas

h. wind power

The Caribbean Region

In the Caribbean region the crude petroleum and refined products share of total merchandise imports increased from less than 9 percent in 1971 to about 25 percent in 1980. Petroleum imports to the Region increased during 1972-77 from $150 million to $620 million in 1980, since all Caribbean countries with the exception of Trinidad and Tobago are net importers of energy.

The Caribbean nations share several energy characteristics:[7]

1) the subcritical size of most national energy systems precludes a choice of solutions;

2) there are no organized markets for indigeneous fuels;

3) indigeneous fuels have not been able to replace the use of imported petroleum;

4) commercially exploitable indigeneous resources are limited;

5) there is a shortage of trained personnel to carry out energy assessments and develop alternative energy programs;

6) national governments resist considering regional cooperative efforts as the best way to approach energy problems.

In the Caribbean, a large amount of imported petroleum is used by the electric utility companies which have peak capacities that range from less than ten megawatts to several hundred

megawatts (See Table 1). The commercial sector demands for electric energy in the smaller islands are frequently dominated by the services (tourist and commerce) industries, in some cases accounting for up to 50 percent of all the electrical energy consumed in the country. Residential electric energy consumption accounts for approximately 20 percent.

To solve the energy problems in the Caribbean Regions we must first recognize that there are a large amounts of natural energy in the area which are not utilized. This situation arises from our own common geographical and ecological circumstances. The potential for renewable energy is only now being recognized by the Region, and some countries are exploring the possibilities for nonconventional sources through research and demonstration.

A consultant for the United Nations Development Programme (UNDP) concluded recently that hydro, geothermal, solar and charcoal alternatives should be developed with priority in the Caribbean. This recommendation generally agrees with the report Energy Resources in the CDCC member countries[8].

The Action Plan for the Caribbean Environment Programme[9] calls for:

1) Assessment of major sources of non-conventional energy and their potentials for utilization.
2) Management will involve:
    a) Cooperation and technical assistance in the application of energy accounting systems which may be used as the basis for the formulation and implementation of sound national energy policies and programmes.
    b) Reinforcement of regional and subregional integrated non-conventional energy activities with the objective of a fuller exchange and dissemination of all available information and provision of training opportunities.
    c) Development of a cooperative programme for the implementation of appropriate technologies and

practices for waste disposal with special attention to recyclying, energy generation and the special problems of the smaller islands.

The sources that are considered in this paper[9] are geothermal, solar, ocean thermal energy conversion, hydropower, biomass, bioconversion and wind.

It is important to mention that the United States Agency for International Development (USAID), with the Caribbean Development Bank (CDB) and CARICOM, as implementing agencies, is financing since 1979 a $7.6 million grant for energy development, including energy planning, assessments, design, testing and dissemination of alternative energy technologies. Based on the achievements of this exercise, feasibility studies will be prepared in support of further financial assistance from regional, multilateral, bilateral and extraregional sources. USAID is in the process of formulating additional assistance projects totalling about $20 million for similar activities in the Dominican Republic, Guyana and Jamaica and for a follow-on project for the Caribbean regions as a whole. Already a USAID loan of $7.5 million has been approved to help Jamaica establish an energy program[10]. Program's goal is to strengthen the island nation's ability to develop and carry out energy projects, expand energy conservation programs and develop alternative energy sources.

Geothermal Power

The whole Caribbean Region is part of the Caribbean Tectonic Plate which occupies most of the Venezuela and the Colombia basins and moves east relative to both the North America Plate on its northern edge, and the South America Plate on the south (See Figure 2). The entire area appears to have been extensively intruded by large bodies of balsaltic magna which developed deep within the mantle of the Earth and moved upward. Active volcanism around the margins of the sea and constant seismic disturbance result in continuous readjustments of the crust[11].

Figure 2

PLATE BOUNDARIES OF THE CARIBBEAN REGION

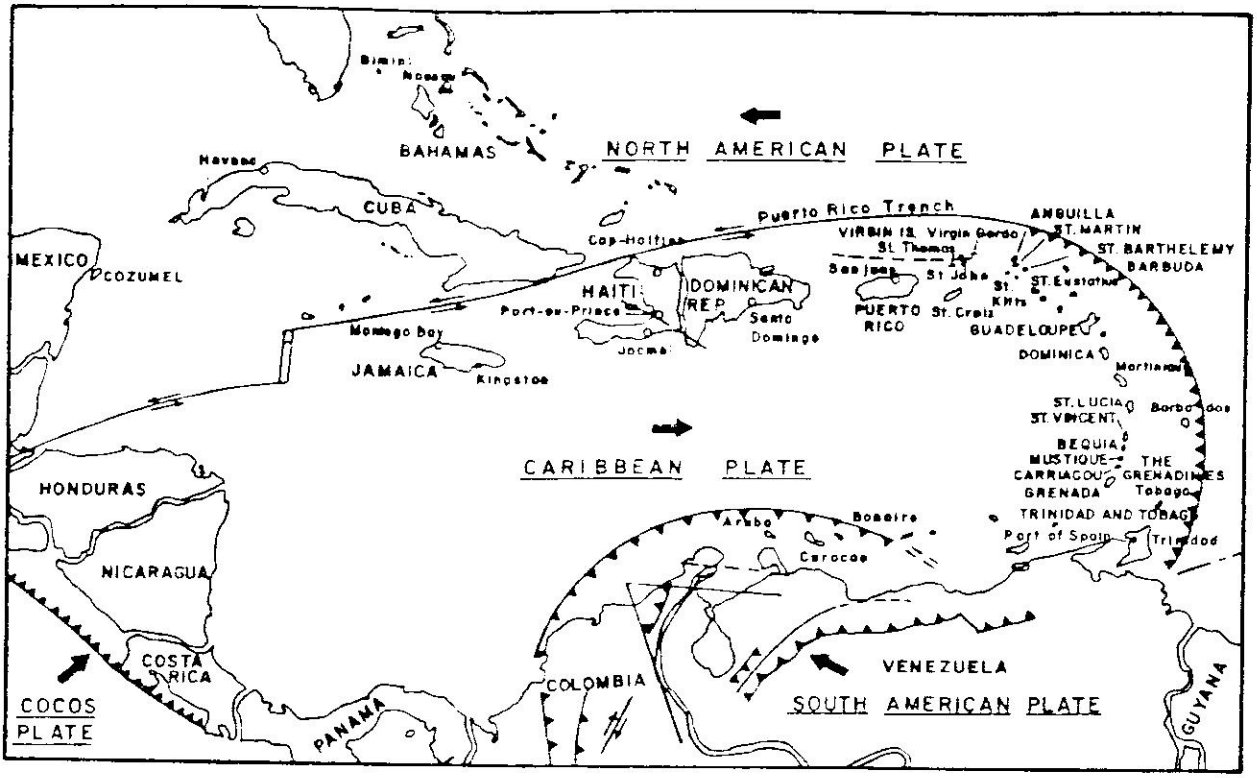
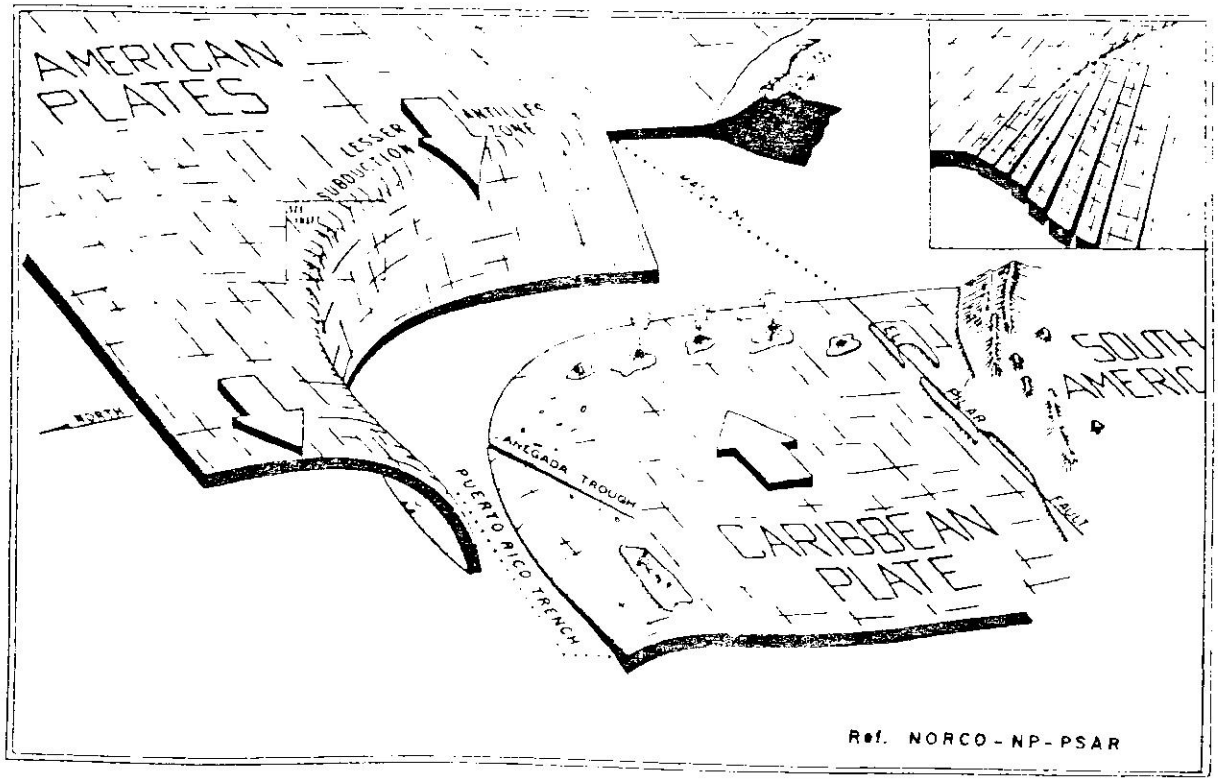


Figure 3

PLATE CONFIGURATION IN EASTERN CARIBBEAN



Regions of geothermal reservoirs are generally located along the margins of major crustal or tectonic plates; the Lesser Antilles is recognized as one of these zones. A tremendous waste of energy in these areas comes from volcanic eruptions, with large amounts of hot (700°C to 1300°C) magna from the mantle being expelled through the crust (See figure 3).

Volcanos exist in the Lesser Antilles. Martinique has the presently inactive Mont Pelee. In Guadaloupe a vein of steam connecting with La Souffriere volcano has been tapped by drilling at Bouvillance off the west coast. This drilling has been capped and, because the pressure is sufficient to operate a geothermal electricity generating station,the necessary plant and equipment has been ordered. Reports of potential geothermal energy resources in Dominica, Montserrat, St. Lucia, St. Vicent, Dominican Republic, Grenada, Haiti and Jamaica have been published. St. Lucia is already planning to develop its thermal source of power at Souffriere with 1 to 5 megawatt units. In 1969, a United Nations study was done in Dominica where the extensive surface manifestations make the geothermal potential quite apparent. In regard to Haiti and Grenada it will be necessary to determine the origin of the hot springs to learn whether they are geochemical or geothermal before any exploratory drilling can be attempted. A feasibil ity study of geothermal is currently underway for generation of electricity in the Dominican Republic.

Geothermal energy has some environmental disadvantages because gases such as carbon monoxide and traces of hydrogen sulphide are capable of polluting the atmosphere. However, this problem can be minimized with the appropriate expertise and resources. It is worth emphasizing that as of today, few attempts have been made at the utilization of geothermal energy for power generation. The major efforts have been made in the state of California, New Zealand, Mexico and Central America.

Solar Energy

Solar Energy as an alternative source of energy has received

the greatest attention in recent times. Essentially all our energy, except nuclear and geothermal, is derived directly or indirectly from the sun. The solar radiation in the Caribbean Region is of the order of two thousand kilowatt hours per square meter per year. Average air temperature varies from about 78°F in February to 83°F in September. Nearly fifteen times more solar radiation reaches the earth's surfaces than the total consumption of commercial energy. Presently, solar energy is used on a very limited scale in the Caribbean for crop drying, water purification, heating and distillation. Two solar stills have been built by a foreign research institutes, one in Haiti and one on St. Vincent in the eastern Caribbean. These stills have been successfully providing potable water to small rural communities. Solar crop-dryers have been built in Grenada for drying nutmegs,in Guyana for chilli peppers, and in Barbados for sugarcane. The application of solar energy for water heating has reached satisfactory levels of development in Jamaica, Barbados and Puerto Rico. By the latest count, there are more than 15,000 solar water heaters in Puerto Rico in residential use. The development of solar industrial steam generators and solar air conditioned units is being pursued by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico. A 1,100 square meters solar air conditioned factory in Canovanas, Puerto Rico, and a new 400 square meters solar air conditioned Post Office in Guayama, Puerto Rico are examples of commercial installations.

In Barbados passive solar designs have been used. An example is the Technical Energy Unit (TEU) building of the Caribbean Development Bank (CDB). Testing of this passive system is in progress. Also a solar air conditioning system has been installed and is being tested in the new Barbados Government Analyst Laboratory. USAID and the Latin American Organization for Energy Development (OLADE) are financing the design and fabrication of a solar system in Haiti at a total cost of $5.5 million.

Ocean Thermal Energy Conversion (OTEC)

Strong ocean surface currents pass through the Caribbean Sea from the Atlantic and continue with increasing speed through the Yucatan channel. The main current flows at an average velocity of about one mile per hour. Also, temperature gradients between the ocean surfaces and 1000 meter depths are more than 22°C (40°F). Great sources of untapped energy exist in these currents and temperature gradients. The maximum depth of the Caribbean Sea is 6,150 meters about 160 kilometer south of Puerto Rico in the Muertos Trough. However, depths of 1000 meters are encountered two kilometers southeast of Puerto Rico. Consequently the CEER is actively working on the development of an OTEC Project on the southeast coast of Puerto Rico[11]. Jamaica is planning an OTEC demonstration project, and the government of Holland has proposed a demonstration project for Curacao where a depth of 5,000 meters can be reached only 1,500 meters offshore. Guadaloupe and St. Croix have made preliminary evaluations of their OTEC potential and Barbados of its wave energy potential on its east coast.

Hydropower

Hydropower is important in Dominica, Haiti and Dominican Republic. Hydropower supplies 90 percent of power generation in Dominica and 27 percent in the Dominican Republic. It could also play an important role in Guyana, Surinam and Jamaica. In Guyana, hydro potential of from 7,200 to 7,600 megawatts has been identified, and in Surinam a hydropower potential of 3000 megawatts exists. Belize is interested in mini hydro projects. A Colombia engineering firm is providing technical assistance to Haiti and Dominica in order to develop small-scale hydroelectric resources[10]. El Centro la Gaviota in Colombia has develop some mini hydro technologies suitable for the region.

Biomass

Sugarcane is growing in many of the Caribbean countries and in large quantities in Barbados, Cuba, Dominican Republic,

Guyana, Haiti, Jamaica, Puerto Rico, St. Kitts-Nevis, Anguila, Trinidad and Tobago. Sugar factories in Haiti are able to satisfy all their energy requirements from bagasse and in Barbados 90 percent of their energy requirements. Considerable use is made of bagasse as fuel for sugarmills in Guyana, Puerto Rico, Jamaica and other countries. Firewood, charcoal and bagasse provide an estimated 80 percent of all primary energy supplies in Haiti.

The energy content of dry bagasse is about 5.15 kilowatt hour per kilogram. An extensive program of more than $1.60 million for the development of bagasse and tropical grasses for energy use has being going on for four years at the CEER in cooperation with the Agricultural Experimental Station. In this program the alternative use of sugarcane to produce both bagasse and the manufacturing of molasses and alcohol has been pursued; also the optimization of tropical grasses for biomass production has been studied.

Bioconversion

Biogas is produced when organic wastes, manure, vegetable matter or human waste are decomposed by bacterial action in anaerobic conditions such as those found in an airtight digester. The biogas produced has a composition of approximately 55 to 65 percent methane (CH_4), 35 to 45 percent carbon dioxide (CO_2), and traces of oxigen, nitrogen and hydrogen sulphide. It is combustible with a calorific value of 20,000 to 25,000 kilo joules per cubic meter, and it can be used for cooking, heating and refrigeration. Once the gas production has ceased in the digester, the residue forms an excellent fertilizer which can be used to grow algae, and the liquid can be extracted for irrigation.

A 1,200 pig farm is being operated successfully by private enterprise in the south of Puerto Rico. All of the electricity at the farm comes from local biogas production, and also algae is grown as a feed supplement for the pigs. For example it has been estimated than the manure from one large dairy cow could yield 2.5 cubic meters of biogas per day, roughly equivalent to

one-third of a gallon of gasoline. It has been estimated that waste from one thousand poultry broilers will be capable of producing about 10 cubic meters of methane per day, energy equivalent to one hundred kilowatt hours per day. If one assumes 30 millions broilers, the energy potential equivalent to the methane produced will be 3 million kilowatt hours per day. Jamaica currently has one unit generating methane from animal wastes and has requested $3.75 million from Kuwait and Iran for a biogas demonstration unit. Barbados has set up three biogas digestors in their Island. Puerto Rico is now designing one large unit to use animal wastes, and the Bacardi Corporation has installed a 3.5 million gallons anaerobic digestor tank to treat their distilleries residue wastes before dumping to the ocean.

The disposal of municipal wastes becames a more serious problem every year because of the continued urbanization of the Caribbean countries. It may be possible for municipal waste to make a substantial contribution to solve both the energy and waste problems by converting the latter to biogas for energy use. San Juan, the capital of Puerto Rico, has plans for such efforts and has also been investigating the methane potential of its present land disposal site.

Winds

Wind energy is the main subject of this seminar, and consequently some aspects of it will be discussed more extensively.

The northeast trade winds prevail over the Caribbean sea. The winds blow consistently from the east or northeast more than 70 percent of the time at means velocities of about 10 miles per hour. Because of this favorable condition, a 200 kilowatt wind power generator was installed by the U.S. Department of Energy (DOE) on the island of Culebra in Puerto Rico. This energy machine is being evaluated at present.

Several of the Caribbean Islands show great suitability for the utilization of wind energy. The Caribbean has had long experience in using wind as a source of energy. Boats have been

powered by wind for many years. Prior to the introduction of machinery for crushing sugarcane, small factories were situated on elevated land in order to use the available wind for driving windmills to crush the cane. This is true for Jamaica, Antigua, Puerto Rico and Barbados. In Antigua the Rockfeller Foundation has financed a 12 kilowatt windmill generator. Also a proposal for two pilot wind generators (50 to 100 kilowatt) has been sent to the United Nations Interim Fund. The Barbados-based Caribbean Meteorological Institute is an active participant in collating information about wind speeds in the Caribbean Region. A wind turbine generator factory has been installed in Puerto Rico by the Future Energy R&D Corporation.

Because of its importance, some comments about the environmental effects of windmills are significant. The impact of wind turbines on the environment can be generally classified in four main areas:

A brief discussion of each of these topics follos:

1) Noise effect

The noise produced by large wind turbine generators is the most objectionable environmental effect. The 2000KW wind turbine generator developed by the U.S. Department of Energy and known as the MOD-1 model was operated for the first time at Boone, North Carolina, in 1980.

During the operation of the machine there was at certain periods (1 percent of the time) a sound amplification or focusing problem raising the noise level to values of up to 77 decibels. This is equivalent to twice the noise level experimented at a busy metropolitan intersection[12]. Some people allegedly became ill and cows were said to have stopped giving milk[13]. In order to reduce the noise level the rotor speed was reduced from 35rpm to 23rpm by modifying the gear reduction box. This apparently has solved the problem.

It should be kept in mind that wind turbines are located in quiet country surroundings and that a little noise may be considered a nuisance to local residents. Efforts must therefore be made to define standards of acceptable noise levels for these environments and then to develop adequate computer programs to predict the noise level of planned wind turbine generators.

2) Radiointerference effects

The rotation of wind turbine blades generate radio-frequency noise which may interfere with TV reception. The MOD-1 machine just mentioned produced serious TV interference for miles around raising the objections of nearby residents. The whirling steel blades of the MOD-1 machine in Boone, North Carolina interfered so much with television reception that the island was wired for cable television[13]. There are various solutions to this problem depending upon the local situation. These solutions include:

a) The use of Cable TV; cable TV, however, is only economical in high population density areas.

b) The use of translators for changing from VHF to UHF. This is very good for sparsely populated areas.

c) The use of high performance antennas. These antennas will pick up a stronger signal from the transmitting TV station. The ratio of signal to noise is larger and the electronic can work properly. The cost of the antenna, however, is high.

3) Air disturbance and reduction of wind power in nearby private properties.

Wind flow pattern is altered by the presence of a wind turbine machine. At optimum operating condition of the turbine the effect might be felt as far as 15 diameters of

the machine rotor. For example, in the original MOD-0 and MOD-1 machines, the windmill faced away from the wind and the tower created a wind shadow that caused an uneven flow of air to the blades. This has been corrected in the new MOD-1 and MOD-2 wind machines where the blades face the wind. For 300ft. diameter rotor machine like the MOD-1 2000KW machine, the effect will be felt for a distance of 4500ft. This could affect the neighbor's wind turbine.

4) Aesthetic effects

Wind turbines can present an objectionable sight when located nearby sophisticated residential areas. For example, the mayor of Desert Hot Springs in California has objected to South California Edison's Plan to build a forest of wind machines there claiming "It will create a visual blight and it has the possibility of destroying our Tourism base."[13]

All environmental impacts of wind turbine appear to be insignificant when compared with other energy sources. Consequently, more than 100 United States electric utilities are considering wind projects[13]. Southern California Edison is already testing wind machines in the San Gorgonio Pass and it has signed agreements to purchase as much as 85 megawatts from 50 wind turbines. Hawaii has signed a contract with Wind Farms, Inc. to install twenty four megawatt wind turbines on Oahu by 1985. Wind Farms, Inc. has persuaded Pacific Gas & Electric Co. to buy as much as 350 megawatts of wind power[14]. Also three 2.5 megawatt wind turbines (MOD-2) are operating at Goodnoe Hills, Washington for the Bonneville Power Administration[15]. The turbine's blades are each 300 feet long; the towers are 200 feet tall; and the blades rotate at 17.5rpm. MAN in Germany is engineering and constructing a Growian (grosse wind energian lage) 3 megawatt wind energy machine[16].

Wind appears as one of the most promising energy alternatives for the Caribbean Region. Coastal winds could be of significance for meeting local energy demands and thereby reducing

investment requirements for transmission and transport of electricity and fuels.

CONCLUSIONS

This paper briefly discussed the renewable energy technologies, geothermal, solar, OTEC, hydro, biomass, bioconversion and wind which have the largest potential for the Caribbean Region. But let's not forget that any activity of man causes some kind of impact on the surrounding. The aim in developing renewable energy technologies is to look for socially desirable, economically viable and ecologically prudent man-made production systems, paradigmatically inspired by the concept of ecosystem, and capable of jointly supplying human necessities. Environmental appears in this perspective as a resource potential to be harnessed on a sustainable basis and, as much as possible, in an ecologically benign manner. We are thus recommending the eco development approach for renewable energy technologies utilization including wind power [17].

Caribbean renewable energies development and potentials are summarized in Table 2. It is important that these renewable energies be examined in the light of four basic forms of energy use, namely: liquid transport fuels, centralized electric power, decentralized power, and heat. These are outlined in Table 3, "New and Renewable Energies Technologies and Applications", prepared for the United Nations Conference on New and Renewable Source of Energy. Among new and renewable energy technologies, minihydro, small-scale solar and biomethanation are already feasible and available for rapid proliferation in a decentralized mode. They can all be used in the Caribbean Region. Table 4 summarizes present demonstration projects in renewable energies in the Caribbean Region. More details of some of these projects are given in Energy Resources in the CDCC member Countries report[8]. Large scale hydro, geothermal and, to some extent, ocean power will continue to play important roles in centralized networks which principally benefit urban areas. The prospects for biomass and peat technologies such as the

production of solid, liquid and gaseous fuels are of considerable interest providing that there are no conflicts with food production. Small-scale solar technologies for water pumping and distillation, low temperature heating, cooking, crop drying, and power generation are available and are expected to play a significant role in the near future. Small and medium-size windmills used in decentralized mode are already cost-competitive in many areas, and medium and large windmills are expected to be attractive enough for autonomous and integrated modes of operation in windy areas such as the Caribbean. For given promising areas, it is important to determine its wind potential and how soon will it become economically competitive.

Other new and renewable energy technologies such as the ocean thermal energy conversion, geothermal energy, large-scale solar ponds, tar sands and oil shales are all very promising. With suitable support for research, development and demonstration these resources could emerge as significant options within short to medium time frames. In order to do the necessary assessments, development and demonstration projects human resources in the Caribbean must be trained and regional programs established utilizing existing institutions in the Caribbean.

REFERENCES

1) "Text of OPEC Communique" - New York Times, October 30, 1981.

2) "A Scared New Wolrd of Third World Energy," Douglas Martin. New York Times, November 1, 1981.

3) United Nations Conference on New and Renewable Source of Energy. Conference News, Ad Hoc Group Reports, Synthesis Report.

4) Latin American Energy Report, Vol. 3, No. 22, October 22, 1981

5) "The Caribbean Rediscovered," New York Times, June 30, 1981.

6) Latin American Plan of Action for the UN Conference on New and Renewable Sources of Energy. A/Conf. 100/7/, March 25, 1981 and A/Conf. 100/8/, April 1981

7) The Caribbean Regions - A Challenge for Alternative Energy Technology Transfer and Development. Ken Soderstrom and Juan A. Bonnet, Jr. Presented at 5th International Scientific Forum on Changes in Energy, Mexico City, Mexico, November 12, 1981.

8) Energy Resources in the Caribbean Development and Cooperation Committee Member Countries, E/CEPAL/CDCC/65. May 28, 1980.

9) Draft Action Plan for the Caribbean Environment Programme, United Nations Environment Programme-UNEP/CEPAL-WG. 48/3. September 16, 1980.

10) Latin American Energy Report, Vol. 3. No. 24, November 19, 1981.

11) Opportunities for Technical Cooperation for the Lesser Antilles with Respect to Development of Alternate Sources of Energy. Juan A. Bonnet, Jr., Conference on Environmental Management and Economic Growth in the Smaller Caribbean Islands, Barbados, September 17-21, 1979.

12) Assessment of Operating Experience with 2MW MOD-1 Wind Turbine Generator. J.L. Collins and R.R. Shaltens, NAS Lewis Research Center, and R.H. Poor and R.S. Barton. The General Electric Co. Paper presented at the Workshop on Large Horizontal-axis Wind Turbines. Cleveland, Ohio, July 28-30, 1981.

13) Wind-Energy Inquiries Show Marked Increases - New York Times December 3, 1981.

14) West Coast Energy Groups feel Winds of Change Around Corner, John Rice, The Hartford Current, September 20, 1981.

15) Wind Farm's First Sprout, V. Elaine Smay; Popular Science, Vol. 219, No. 5. November 1981.

16) Construction Starts on Growian 3 MW Wind Machine. Modern Power Systems, Vol. 1, Issue 7, July/August 1981.

17) Energy/Environment Management: A Broad Perspective for the Islands of the Caribbean. Juan A. Bonnet, Jr. and Edward L. Towle. Background paper for Workshop II on Energy/Environment Projects for the Caribbean Area. Key Biscayne, Florida, March 19-20, 1981.

TABLE 1

ELECTRICITY CAPACITY AND PRODUCTION IN 2000 ISLANDS AND COUNTRIES IN THE CARIBBEAN

	A	B	C	D	E	F	G	H
Island or Country	(1) Area (km^2)	(1) Population (thousands	(2) Installed Electricity Capacity (Megawatts)	(2) Yearly Electricity Production (Millions of kwh)	(3) Electricity Production Per Capita (EPPC) (kwh/person)	(4) Gross National Product (GNPPC) (US$/person)	(4) EPPC GNPPC (kwh/US$)	(5) Refinery Capacity thousands barrels/day
Antigua	435.2	4	26	53	716	950	0.75	18
Bahamas	NA	218	255	675	3,096	2,620	1.18	500
Barbados	425	250	105	266	1,164	1,940	0.6	3
Colombia	1,139,000	25,600	3,850 d/	15,343 d/	600	870 e/	0.68	162
Cuba	115,000	10,000	1,876	7,750	775	810	0.96	134
Curacao-Aruba				---	---	---	---	
Dominica	42.4	77	6	16	208	440	0.47	11.8
Dominican Republic	49,000	5,128	900	2,763	539	910	0.59	90
Grenada	307	106	7	28	264	530	0.5	NA
Guyana		812	180	425	523	560	0.94	0
Haiti	28,000	4,800	102	276	57.5	260	0.22	0
Jamaica	11,000	2,100	705	2,130	1,014	1,150	0.88	33
Martinique d/	1,088	369	55	194	526	2,900	0.18	10.3
Mexico	1,972,947 a/	a/	12,847 d/	46,612 d/	696 d/	1,374.3 a/	0.51	509 d/
Monserrat	100	12.7	4	10 c/	787	920	0.85	0
Puerto Rico	8,960	3,176	4,207 b/	11,121 b/	3,502 b/	3,172 b/	1.10	289 f/
St. Kitts-Nevis	166	50	13	27	540	660	0.81	0
St. Lucia	589	120	15	50	417	630	0.66	0
St. Vicent	384	106	9	20	189	380	0.49	0
Trinidad & Tobago	5,000	1,137	454	1,640	1,442	2,910	0.5	431
Venezuela	912,000	13,965	6,119 e/	23,276 d/	1,666	2,910	0.6	1,453

1. Informe Sobre El Desarrollo Mundial, Agosto 1980/Data 1978
2. Energy Resources in the CDCC Member Countries, El CEPAL/CDCC/65 28 May 80/Data 1978
3. From Column D an B
4. Informe Sobre El Desarrollo Mundial, Agosto 1980 and columns F and E
5. (i) Organización de las Naciones Unidas para el desarrollo industrial, 7 Agosto 1979
   Proyecto PNUMA/CEPAL "Esquema de la Energía y El Ambiente en la Zona del Caribe
   (ii) Energy Resources in the CDCC Member Countries, EL CEPAL/CDCC/65 28 May 1980

a. Data 1980/Energy in Mexico
b. Data 1980 - Puerto Rico in Figures 1980, GDBPR
c. Data 1979 -
d. Data 1976
e. Data 1978
f. Data 1979

N.A. not available

TABLE 2

DEVELOPMENT AND POTENTIAL OF ENERGY RESOURCES IN THE CARIBBEAN

(ENERGY RESOURCES)

Island or Country	Oil and Gas	Coal	Hydropower	Geothermal Energy	Biomass Energy	Solar Energy	Others (Wind, etc.)
Antigua	1a	1a	1a	2a	2a	5a	5a
Bahamas	2a	1a	1a	2a	2a	5a	5a
Barbados	3b	1a	1a	2a	4b	4a	5a
Colombia	4d	1c	5d	2a	5b	4a	5a
Cuba	3c	2a	3b	2a	5b	5a	5a
Dominica	1a	1a	4c	2a	2a	4a	5a
Dominican Republic	2a	2a	3b	2a	5a	5a	5a
Grenada	2a	1a	2a	2a	2a	4a	5a
Guyana	2a	1a	5b	1a	5b	4b	5b
Haití	2a	1a	3b	2a	4a	5a	5a
Jamaica	2a	2b	3b	2a	5b	5a	5a
Martinique	1a	1a	1a	2a	4b	4a	5a
Mexico	5d	5c	5c	4c	5b	5a	5a
Monserrat	1a	1a	1a	2a	2a	4a	5a
Puerto Rico	1a	1a	3b	2a	4b	5c	5a
St. Kitts-Nevis	NA	NA	NA	NA	NA	NA	5a
St. Lucia	1a	1a	1a	3a	2a	4a	5a
St. Vicente	1a	1a	3c	2a	2a	4a	5a
Trinidad/Tobago	5a	1a	1a	2a	3b	4a	5a
Venezuela	5d	2b	5c	2a	4b	4a	5a
Virgin Islands (U.S.)	1a	1a	1a	2a	2a	5a	5a

Potential
1. poor
2. not determined but possible
3. limited
4. medium
5. important

Development
a. without development
b. limited development
c. medium development
d. good development

Data from:
Esquema de la energía y el ambiente en la zona del Caribe, 7 de agosto de 1979, Organización de las Naciones Unidas

NA - Not Available

TABLE 3

NEW AND RENEWABLE ENERGY TECHNOLOGIES AND APPLICATIONS

Energy Sources	Liquid Transport Fuels	Centralized Electric Power	Decentralized Power	Heat
1. Solar		Thermal electric Photovoltaic Solar pond	Thermal electric Photovoltaic	Solar passive Solar pond Solar flat plate Evacuated tubed Solar cookers Solar concentrators
2. Geothermal		Geothermal electric	Geothermal small power	Geothermal Direct heat
3. Wind		Wind electric	Wind electric Wind shaft	
4. Hydropower		Hydropower (including small hydro)	Minihydro	
5. Biomass	Ethanol Methanol Vegetable oils	Direct combustion	1) Diesel with liquid biofuel 2) Diesel with producer gas 3) Diesel with biogas 4) Direct combustion 5) Fuel cells based on liquid/gas fuel	1) Direct combustion 2) Biogas 3) Producer gas
6. Fuelwood and Charcoal		Direct combustion		Direct combustion of wood and charcoal
7. Oil Shale and Tar Sands	Syncrude	Shale burning		Liquid fuel for cooking
8. Ocean energy		Tidal OTEC Wave	Wave	
9. Peat	Methanol	Direct combustion	1) Direct combustion 2) Gasification	Direct combustion
10. Draught Animal			Traction and shaft power	

TABLE 4

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Antigua	1. Renewable Energy-Wind	Wind Generators (50-100 KW)	UN Interim-Fund
	2. Renewable Energy-Wind	Wind Generators (12KW)	Rockefeller Fund
	3. Renewable Energy-Solar	Photovoltaic pumping System	CDB
Bahamas	1. Oil	Exploration	UNDP/IBRD
Barbados	1. Renewable Energy-Biomass	Bagasse Burning Studies	CIDA/CDB
	2. Renewable Energy-Wind	Pilot Generator (200 KW)	IDB
	3. Renewable Energy-Biogas	Biogas Digestors	CDB
	4. Renewable Energy-Solar	Solar Air Conditioning	USAID/CDB
	5. Renewable Energy-Solar	Solar Collector Manufacturing	USAID/CDB
Curacao	1. Renewable Energy-Wind	Wind Turbine for Cooling	Dutch University
Dominica	1. Hydro	Hydro Electric Study	CDB
	2. Hydro	Workshop (3/81)	CDB/TCU
	3. Geothermal	Preliminary Study	Belgium
	4. Renewable Energy-General	Regional Research Center	OAS
	5. Renewable Energy-Biomass	Prefeasibility Vegetable Waste Boiler	CDB
Dominican Republic	1. Renewable Energy-Hydro	Development	Venezuela
	2. Energy Farms	Investigations & Development	AID
	3. Renewable Energy-Solar	Investigations & Development	OAS
	4. Renewable Energy-Wind	Investigations & Development	OAS
	5. Renewable Energy-Biomass	Development	IDB
	6. Renewable - Bioconversion	Alcohol Production	Brasil
	7. Renewable-Wind	Wind Turbine	OLADE
	8. Renewable Energy-Geothermal	Investigations	OLADE
Grenada	1. Hydro	Hydrological Resource Assessment	Venezuela
	2. Hydro	Micro-Hydro Identification	OLADE
	3. Renewable Energy-Biogas	Biogas Unit Comparison	OLADE

TABLE 4

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Mexico	1. Renewable Energy-Solar	Water Pumping	West Germandy and France CONACYT
	2. Renewable Energy-Solar	Rural Electrification	France - CONACYT
	3. Renewable Energy-Solar	Solar Research and development projects	Canada and Israel-CONACYT
	4. Coal	Exploration	National Energy Commission (Comisión Nacional de Energía)
	5. Renewable-Hydro	Investigations	National Energy Commission
	6. Renewable-Geothermal	Development	National Energy Commission
Monserrat	1. Hydro	Mini-Hydro Development	IDB
	2. Geothermal	Geothermal Development	USAID
Puerto Rico	1. Renewable Energy-Solar	Water Heating for Industry and Agriculture	DOE
	2. Renewable Energy-Solar	Air Conditioning	DOE
	3. Renewable Energy-Wind	Wind Turbine-Culebra	NASA-DOE-PREPA
	4. Renewable Energy-Bioconversion	Production of gas	Goddar Space Laboratory-NASA
	5. Renewable Energy-Biomass	Biomass from Sugar Cane and Tropical Grasses	DOE

DATA FROM: International Bank for Reconstruction and Development - June 9, 1981

St. Kitts-Nevis	1. Electricity	Generation and Transmission Development	CDB

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Guyana			
	1. Renewable Energy-Biomass	Technical Assistance, Ethanol Production	Brasil
	2. Renewable Energy-Biomass	Utilization of Rice Husks	USAID
	3. Renewable Energy-Biomass	Gasification of Wood Waste; Oil-to-Charcoal conversion of alumina and bauxita kilns	IBRD
	4. Renewable Energy-Biomass	Utilization of Wood Waste	IDB / UNICEF
	5. Renewable Energy-Solar	Solar component in the regional program	USAID/CDB
Haiti	1. Hydro	La Chapel Hydro Project Feasibility Study	IDB
	2. Renewable Energy-Biomass	Reforestation	USAID, IDB
	3. Renewable Energy-Biomass	Appropriate Technology Center (charcoal)	USAID
	4. Renewable Energy-Biogas	Biogas Study	OAS
	5. Renewable Energy-Solar	Solar System Manufafacturing	USAID/OLADE
Jamaica	1. Hydro	Hydro Development	Sweden
	2. Hydro	Hydro Development	IDB
	3. Renewable Energy-General	Alternative Energy Technologies	OAS
	4. Renewable Energy-General	Assessment of Nonconventional Energy	IDB
	5. Renewable Energy-General	Recycling of lube oil	IBRD
	6. Renewable Energy-Biomass	Charco Project	IDB
	7. Renewable Energy-Biogas	Biogas Demostration Unit	OAS
	8. Renewable Energy-Solar	Solar component in the regional program	USAID/CDB

ABBREVIATION AND ACRONYMS

1)	AID	-	Agency for International Development
2)	BDD	-	British Development Division of the Ministry of Overseas Development. U.K. Government
3)	CDB	-	Caribbean Development Bank
4)	CIDA	-	Canadian International Development Agency
5)	CONACYT	-	Consejo Nacional de Ciencia y Tecnología México
6)	DOE	-	Department of Energy (U.S.)
7)	EDF	-	European Development Fund
8)	EIB	-	European Investment Bank
9)	IBRD	-	International Bank for Reconstruction and Development (World Bank)
10)	IDB	-	Inter-American Development Bank
11)	NASA	-	National Air Space Administration (U.S.)
12)	OAS	-	Organization of American States
13)	OLADE	-	Latin American Organization for Energy Development
14)	PREPA	-	Puerto Rico Electric Power Authority
15)	TEU	-	Technical Energy Unit
16)	UN	-	Interim-Fund - United Nations Interim-Fund
17)	UNDP	-	United Nations Development Programme
18)	UNICA	-	Caribbean Universities and Research Institutes Association
19)	UNICEF	-	United Nations International Children's Emergency Fund
20)	USAID	-	United States Agency for International Development