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STATUS OF RENEWABLE ENERGY PROGRAMS IN CARIBBEAN ISLANDS

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ABSTRACT

The Caribbean is a complex region of different peoples, cultures, economies and resource bases. With the exception of one, all are dependent almost entirely on imported oil to meet their energy needs. Yet there are significant opportunities to develop their renewable energy resources. Research, development, demonstration, and to some extent distribution of renewable energy systems have begun. These range from research into OTEC, solar ponds, windmills and solar cooling.

In part the impetus to develop these systems comes from assistance from outside the Caribbean. Indigenous competencies are increasing, however. In recent years the level of effort has increased significantly, to the extent that renewable energy programs exist throughout the region.

INTRODUCTION

The problems surrounding energy and eco- nomic development of islands are not new. Infrastructure problems are many. Reliable electric supply is always difficult to maintain and outages are frequent. Fuel is frequently imported. Necessary skilled maintenance personnel for generating equipment and electricity distribution systems are not available.

On the other hand small islands may in some instances have advantages not generally shared by other developing economies. Of particular interest are the energy opportunities associated with coastal activities. The potential for coastal and ocean related energy resource development may have wider scope on small islands. It is nevertheless very important to provide the overall energy planning framework in which coastal related energy demands and resources can be usefully situated.

Some of the objectives shared by many less developed countries and islands include the development of skills and a diversified labor force, overcoming chronic unemployment, substantial improvement of infrastructure, expansion of services and industrial capacity and stabilization and modernization of the rural sector. This demands substantial input of capi- tal and energy. Economic development has been linked historically to increasing energy consumption per capita. On the other hand, the type and magnitude of energy required to produce a given set of goods can vary widely depending on the processes employed, the spatial configuration of supply and demand, and the efficiency of energy conversion. Indeed, least-cost strategies for achieving a given output show that energy consumption can be reduced dramatically and in a cost effective way. The less developed countries including islands have a great opportunity to incorporate appropriate levels of energy use efficiency in their vehicles, buildings and equipment at an early stage.

The issue of agriculture and energy is of fundamental importance, first in the use of biomass to provide the energy basis for increasing agricultural productivity. But also the trade-off between agriculture for energy or for food will remain controversial. However, the great diversity in ecology, topography, climate, economic activity and demography among small islands makes it difficult to make broad generalizations, except that each must address its particular circumstances. This diversity in the Caribbean is reflected in Table 1.

Small economies generally and small islands in particular suffer from a number of diseconomies associated with small scale activities. Also many commodities are imported. On islands in particular it may be difficult to establish self-sufficiency in either or both food and energy because of limited land, resources and the need to maintain export crop production.

The legacy of colonialism and current conditions can foster continued dependence on external sources of administrative, technical and management skills. Islands use as electric power what they inherited from their mother country. Consequently, they continue to depend on their foreign expertise and spare parts. So too the historic experience with monoculture fishing is many times constrainted by conditions of relatively low productivity and the high cost of input similar to agriculture. Physical conditions on small islands can also contribute to specific problems like soil and coastal erosion and other natural phenomena such as hurricanes, earthquakes, high tides, and winds which can affect the whole economy and ecology of small islands.

On some small islands there may be an insufficient diversity of ecological conditions to sustain a wide range and adequate level of domestic economic activities. Arable land is often relatively scarce, and mineral resource lacking. In other cases the absence of rivers or island water bodies force dependence on rain catchments for water supply. Also the brackishness of some of the water supply limits water resources. An absence of natural earth renewal also causes problems.

On many small islands the warm climate and ocean water beaches attract tourists who contribute to economic growth. These resources also provide opportunity for energy development. The sector's demand for electric energy in the smaller islands is frequently dominated by the tourist industry. Industrial activities on islands are generally based upon fossil fuels, especially oil, which is more readily transported and available than coal. There are a number of coastal specific energy consuming activities which influence the overall demand configuration. These includes transport, harbor maintenance, port facilities, boat building, coast guard, resort recreation, fishing and fish processing, commercial and administrative activities that are concentrated in coastal urban cities. The coastal environment offers special advantages for electricity generating units, including availability of large amounts of water for open cycle cooling and ready access to imported fuels. Disposal of waste is also relatively easier and cheaper than elsewhere. In small islands with a limited conventional resource base coastal location of central station power plants may be the only viable option. Facilities for storing, handling and distributing petroleum also exist in coastal areas. Some small islands import crude oil for refining to meet domestic needs and for export.

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 into the Region increased during 1972-77 from $150 million to $620 million in 1980, since all Caribbean countries with the exception of Trinidad-Tobago are net importers of energy.

The Caribbean nations share several energy characteristics (15).

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

2. there are no organized markets for indigenous fuels;

3. indigenous fuels have not been able to replace the use of imported petroleum;

4. commercially exploitable indigenous 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 proportion 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 3). The commercial sector demands for electric energy in the smaller islands are frequently dominated by the services industries (tourism and commerce), in some cases accounting for up to 50 percent of all the electrical energy consumed in a country. Residential electric energy consumption accounts for approximately 20 percent.

To solve the energy problems in the Caribbean Region the first fact that must be recognized is that there are large amounts of natural energy in the area which are not being utilized. This situation arises from 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 number of governments and international organizations has focused attention and assistance on energy issues in developing countries in general and Caribbean islands in specific. The Mexican and Venezuelan governments are implementing an important oil purchasing financing agreement for the Caribbean. 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. 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 mass 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) such as Caribbean Islands 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(14):

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

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.(9)

The Action Plan for the Caribbean Environment Programme (10) calls for:

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 programs.

b. Reinforcement of regional and subre- gional 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 recycling, energy generation and the special problems of the smaller islands.

Energy sources considered in the Action Plan 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, assessment, 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-up project for the Caribbean region as a whole. Already a USAID loan of $7.5 million has been approved to help Jamaica establish an energy program.(11) The goal of the program is to strengthen the island nation's ability to develop and carry out energy projects, expand energy conservation programs and develop alternative energy sources.

Through the auspeces of the Association of Caribbean Universities and Research Institutions (UNICA) a network among academic and other of power at Souffriere with 1 to 5 megawatt units. 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 feasibility study of geothermal potential 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 at present, few attempts have been made to utilize geothermal energy for power generation. The major efforts made have been in 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. Nearly fifteen times more solar radiation reaches the earth's surfaces than the total consumption of commercial energy. The potential is even greater in the Caribbean Region. The solar radiation in the Caribbean Region is on the order of two thousand kilowatt hours per square meter per year. Average air temperature varies from about 25°C (78°F) in February to 27.5°C (83°F) in September. 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 institute, one in Haiti and one in St. Vincent in the eastern Caribbean. These stills have been successfully providing potable water to small rural communities. Solar crop-dryers have been built for drying nutmegs in Grenada, chili peppers in Guyana, and sugar cane in Barbados. The application of solar energy for water heating has reached satisfactory levels of development in Jamaica, Barbados and Puerto Rico.

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.

The largest solar hot water system in the Caribbean opened in September 1981 at the Cornwell Regional Hospital in Jamaica. The project was sponsored by the Citizens Energy Corporation.

The Caribbean has almost everything in its favor to make solar industrial energy a success. It has an outstanding availability of direct (concentratable) sunshine; an increasing well-documented insolation data base in Puerto Rico; high energy costs; a large established tourist industry which requires extensive air conditioning; a well established petrochemical industry in such islands as Trinidad, Curacao, the Virgin Islands and Puerto Rico. If one wants to try out a new idea, one tries it either in the most favorable economic environment, or at the location where one has the greatest control over its operation. The fabrication of inexpensive collector by unskilled labor is one such example. Solar hot water heaters are already being fabricated in many of the islands. In Puerto Rico, a flexiglass solar concentrator collector for air conditioning systems has been developed and is being fabricated.

Ocean Thermal Energy Conversion (OTEC)

As a potential source for commercial supplies of electrical energy, ocean thermal energy conversion (OTEC) offers another viable answer. It could become one of the most economical sources of energy yet conceived and is abundantly available as a potential source of power for generating electricity. The thermal (including gulf currents) energy potential of the Caribbean is estimated at 182 billion KwHr per year.(3)

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 2 km. 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 south-east of Puerto Rico. Until recently CEER had been actively working on the development of an OTEC project on the southeast coast of Puerto Rico. Its floating platform laboratory had run longer, continuously, than any other similar data-gathering station in the world.(3) Jamaica is planning an OTEC demonstration project in conjunction with the governments of Finland, Norway and Sweden through a consortium established for the purpose.(1) 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. Guadeloupe and St. Croix have made preliminary evaluations of their OTEC potential and Barbados on its east coast, of the wave energy potential on its east coast.

Hydropower

Hydropower is important in Dominica, Haiti and the 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 3,000 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.(13) El Centro La Gaviota in Colombia has developed some mini hydro technologies suitable for the region.

Biomass

Broadly defined, biomass consists of terrestrial and aquatic vegetation and its residues and wastes, including animal wastes. Biomass is essentially a renewable and indirect form of solar energy - sunlight powering the chemical reaction which converts CO_2 and water into solid green water and oxygen.

The sub-tropical climate of the Caribbean is ideal for biomass and has been recognized for its abundance in producing a major form of biomass in the past, i.e., sugar cane.

Sugarcane is grown in many of the Caribbean countries and in large quantities in Barbados, Cuba, Dominican Republic, Guyana, Haiti, Jamaica, Puerto Rico, St. Kitts-Nevis, Anguila and Trinidad and Tobago. Sugar factories in Haiti are able to satisfy 100 percent of 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 Guayana, Puerto Rico, Jamaica and other countries. Firewood, charcoal and bagasse provide an estimated 80 percent of Haiti's total primary energy supplies.

The energy content of dry bagasse is about 5.15 kilowatt hours per kilogram. An extensive program of more than $1.60 million for the development of bagasse and tropical grasses for energy use has been going on since 1978 at CEER in cooperation with the Puerto Rico Agricultural Experimental Station. In this program the alternative use of sugarcane to produce both bagasse and the manufacture of molasses and alcohol has been pursued; also the optimization of tropical grasses for biomass production has been studied. A short ton of "ovendry" biomass (6 percent moisture) contains about 15 million BTU of energy. This is the equivalent of two 42 gallon barrels of residual fuel oil. In addition, a significant amount of sugar and high test molasses are also produced. It has been estimated by CEER scientists that 70,000 acres planted in energy cane would produce yields roughly doubling present sugar production, eliminate entirely Puerto Rican rum industry 80 percent dependence on imported molasses, and reduce Puerto Rico's petroleum imports by 17 percent.(5)

Studies currently suggest that costs would approximate about $2,500 to $2,700 per hectare and yield fiber and molasses product valued in excess of $7,400 per hectare. In sum, in spite of inflation and rising labor and other costs, it is possible at present to plant energy cane in Puerto Rico and produce it at less than $1.10 per million joules.

Puerto Rico is geographically and historically typically Caribbean and well positioned to embark on a biomass energy industry. Located roughly 18° north latitude, its tropical climate can sustain plant growth on a year-round basis. Temperatures rarely drop below 15°C (60°F). There are literally thousands of plant species, both woody and herbaceous, capable of utilizing this climate for continuous growth processes. Approximately 80 percent of the land mass is "humid", i.e., it receives abundant rainfall, while irrigation is well developed in the remaining arid regions. There are six distinct ecological life zones. The lands themselves offer varied selection for both research and commercial development. Of Puerto Rican soils there are 9 Orders, 27 Suborders, 37 Great Groups, 54 Families, and 163 Series. It thus represents nearly all the Caribbean in all its variety.

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 oxygen, nitrogen and hydrogen sulphide. It is combustible with a calorific value of 20,000 to 25,000 kilo joules per cubic meter, and 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. 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 1.25 litres 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 digesters. Puerto Rico is preparing an energy-integrated farm on the semi-arid South Coast. The farm has a current milking herd of 500 registered Holsteins. The farm's 1982 average power demand was about 1,680KwH/day, and 2160 kg. of solid waste was produced daily. The proposed energy integration system has two functions: (a) to produce green feed, electricity, and high-protein feed substitutes from manure, and (b) to establish a waste management system in compliance with Puerto Rico's environmental quality regulations. The energy-integration complex consists of eight subsystems. These include components for manure preparation and blending, a biogas generation subsystem, producing approximately 350 cm per day, a biogas utilization subsystem, a solids dewatering and drying subsystem, and subsystems for wastewater cleaning and recycling. A monitoring subsystem is included to assure compliance with environmental regulations. From 30 to 40 percent of dairy feed requirements and 60 to 80 percent of farm power needs will be provided by the integrated system. Also in Puerto Rico, the Bacardi Corporation has installed a 13.5 million litre anaerobic digester tank to treat their distillery residue wastes before dumping them into the ocean.

Disposal of municipal wastes becomes an increasingly serious problem every passing year because of continuing urbanization of Caribbean countries. It may be possible for municipal waste to make a substantial contribution to solving both the energy and waste problems by converting the latter to biogas for energy use. San Juan, the capital of Puerto Rico, has been investigating the methane potential of its present land disposal site.

Winds

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 mean velocities of about 16 km 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 has produced 584,990KwHr of energy from 1978 to 1981, despite down time to improve blade performance and despite the occurence of a labor strike. The project is being continued. A salient finding has, however, been the need to involve the community in such projects. In Culebra, although the residents favored wind energy as an alternative, their perception of their own wind mill's performance was largely negative, due to lack of participation and preparation.

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.

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 the wind potential and how soon wind will become economically competitive.

Caribbean Options

A variety of renewable energy options for the Caribbean have been reviewed. In light of the great diversity in the Region, not all are appropriate for each. However with suitable support for research, development and demonstration, the Caribbean can provide an even increasing share of its energy needs.

It is clear that just transferring hardware does very little toward building a technology oriented economy. It is more important to provide for a broad capability in the population to design, plan, select, manage, maintain and analyze suitable choices of technological systems. During the 1979 UN Conference on Science and Technology for Development, two different views emerged regarding the main obstacle to Third World development: first, lack of infrastructure and second, the degree of control that developed countries exercise over technology. The effective solution should both eliminate barriers and provide new opportunities based on mutual confidence.

In order to do that in each particular island the following must be done:

1. Evaluate human and natural resources;
2. Identify needs and goals;
3. Select the most appropriate technologies needed;
4. Develop methods to introduce the technology.

All of this must be done while maintaining the delicate ecological balance of the islands and givin high priority to their cultural preferences. The active participation of local personnel in all steps is indispensable. It is not an easy task because of the great diversity among islands and that is what makes it a great challenge. The survival of many small islands depends on achieving this necessary balance.

Let us not forget that any activity of man causes some kind of impact on the surroundings. 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 ecosystem concept, and capable of jointly supplying human necessities. Environment appears in this perspective as a supply resource potential to be harnessed on a sustainable basis and, as much as possible, in an ecologically benign manner. The eco development approach for renewable energy technologies utilization including wind power is more suitable.(11)

Caribbean renewable energies development and potentials are summarized in Table 4. 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. 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 5 summarizes present demonstration projects in renewable energies in the Caribbean Region. More details of some of these projects can be found in Energy Resources in the CDCC member countries report.(10)

CONCLUSION

Broadly speaking, there are three major categories of energy planning options: (1) fuel switching especially away from oil; (2) improving conversion and end use efficiency; and (3) developing indigenous resources, especially the new and renewable. When comparing alternative energy policies, programs or strategies it is important to establish their economic, cultural and environmental impacts. To this end costs and benefits must be carefully evaluated.

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TABLA I

CONSUMO DE MIELES EN PUERTO RICO:
RELACION DE PRODUCCION LOCAL VS. DEMANDA, 1960-1983
(Millones de galones)

Zafra	Destilación de Ron (g.p.)	Consumo Mieles Industria Ron	(Estimado) Otros Usos	Consumo Total Estimado	Producción Total de Mieles (Gals.)	Cambio (Producción vs. Consumo)
1960	7.2	10.1	10.0	20.1	58.4	+38.3
1961	7.2	10.1	10.0	20.1	62.4	+43.3
1962	9.7	13.6	10.0	23.6	56.2	+32.6
1963	12.7	17.7	10.0	27.7	61.3	+33.6
1964	11.4	16.0	10.0	26.0	64.3	+38.3
1965	12.2	17.1	10.0	27.1	57.2	+30.0
1966	14.5	20.3	10.0	30.3	60.6	+30.3
1967	13.4	18.8	11.0	29.8	52.1	+22.3
1968	15.0	21.0	11.5	32.6	43.9	+11.3
1969	17.3	24.2	12.4	36.6	41.6	+ 4.8
1970	15.5	21.8	10.9	32.7	45.4	+12.7
1971	18.0	25.2	11.0	36.2	30.9	- 5.3
1972	24.0	33.7	11.0	44.7	28.3	-16.4
1973	21.2	29.7	11.0	40.7	24.9	-13.2
1974	19.8	27.8	11.0	38.8	22.9	-15.8
1975	18.4	25.8	11.0	36.8	23.6	-13.2
1976	24.9	34.9	11.0	45.9	21.0	-24.9
1977	27.7	38.8	11.0	49.8	21.1	-31.7
1978	28.1	39.4	11.0	50.4	17.8	-33.0
1979	35.3	49.4	8.0	57.4	13.9	-43.2
1980	32.1	44.9	8.0	52.9	14.0	-38.9
1981	31.3	43.8	8.0	51.8	12.4	-39.4
1982	30.0	42.0	6.0	48.0	12.1	-35.9
1983	33.1 (e)	46.3(e)	6.0	52.3	10.5	-41.8

g.p. = galón prueba

(e)= Estimado

Fuente : Referencia Número 4

TABLA I

CONSUMO DE MIELES EN PUERTO RICO:
RELACION DE PRODUCCION LOCAL VS. DEMANDA, 1960-1983
(Millones de galones)

Zafra	Destilación de Ron (g.p.)	Consumo Mieles Industria Ron	(Estimado) Otros Usos	Consumo Total Estimado	Producción Total de Mieles (Gals.)	Cambio (Producción vs. Consumo)
1960	7.2	10.1	10.0	20.1	58.4	+38.3
1961	7.2	10.1	10.0	20.1	62.4	+43.3
1962	9.7	13.6	10.0	23.6	56.2	+32.6
1963	12.7	17.7	10.0	27.7	61.3	+33.6
1964	11.4	16.0	10.0	26.0	64.3	+38.3
1965	12.2	17.1	10.0	27.1	57.2	+30.0
1966	14.5	20.3	10.0	30.3	60.6	+30.3
1967	13.4	18.8	11.0	29.8	52.1	+22.3
1968	15.0	21.0	11.5	32.6	43.9	+11.3
1969	17.3	24.2	12.4	36.6	41.6	+ 4.8
1970	15.5	21.8	10.9	32.7	45.4	+12.7
1971	18.0	25.2	11.0	36.2	30.9	- 5.3
1972	24.0	33.7	11.0	44.7	28.3	-16.4
1973	21.2	29.7	11.0	40.7	24.9	-13.2
1974	19.8	27.8	11.0	38.8	22.9	-15.8
1975	18.4	25.8	11.0	36.8	23.6	-13.2
1976	24.9	34.9	11.0	45.9	21.0	-24.9
1977	27.7	38.8	11.0	49.8	21.1	-31.7
1978	28.1	39.4	11.0	50.4	17.8	-33.0
1979	35.3	49.4	8.0	57.4	13.9	-43.2
1980	32.1	44.9	8.0	52.9	14.0	-38.9
1981	31.3	43.8	8.0	51.8	12.4	-39.4
1982	30.0	42.0	6.0	48.0	12.1	-35.9
1983	33.1 (e)	46.3(e)	6.0	52.3	10.5	-41.8

g.p. = galón prueba

(e)= Estimado

Fuente : Referencia Número 4

TABLA I

CONSUMO DE MIELES EN PUERTO RICO:
RELACION DE PRODUCCION LOCAL VS. DEMANDA, 1960-1983
(Millones de galones)

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1977	27.7	38.8	11.0	49.8	21.1	-31.7
1978	28.1	39.4	11.0	50.4	17.8	-33.0
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1977	27.7	38.8	11.0	49.8	21.1	-31.7
1978	28.1	39.4	11.0	50.4	17.8	-33.0
1979	35.3	49.4	8.0	57.4	13.9	-43.2
1980	32.1	44.9	8.0	52.9	14.0	-38.9
1981	31.3	43.8	8.0	51.8	12.4	-39.4
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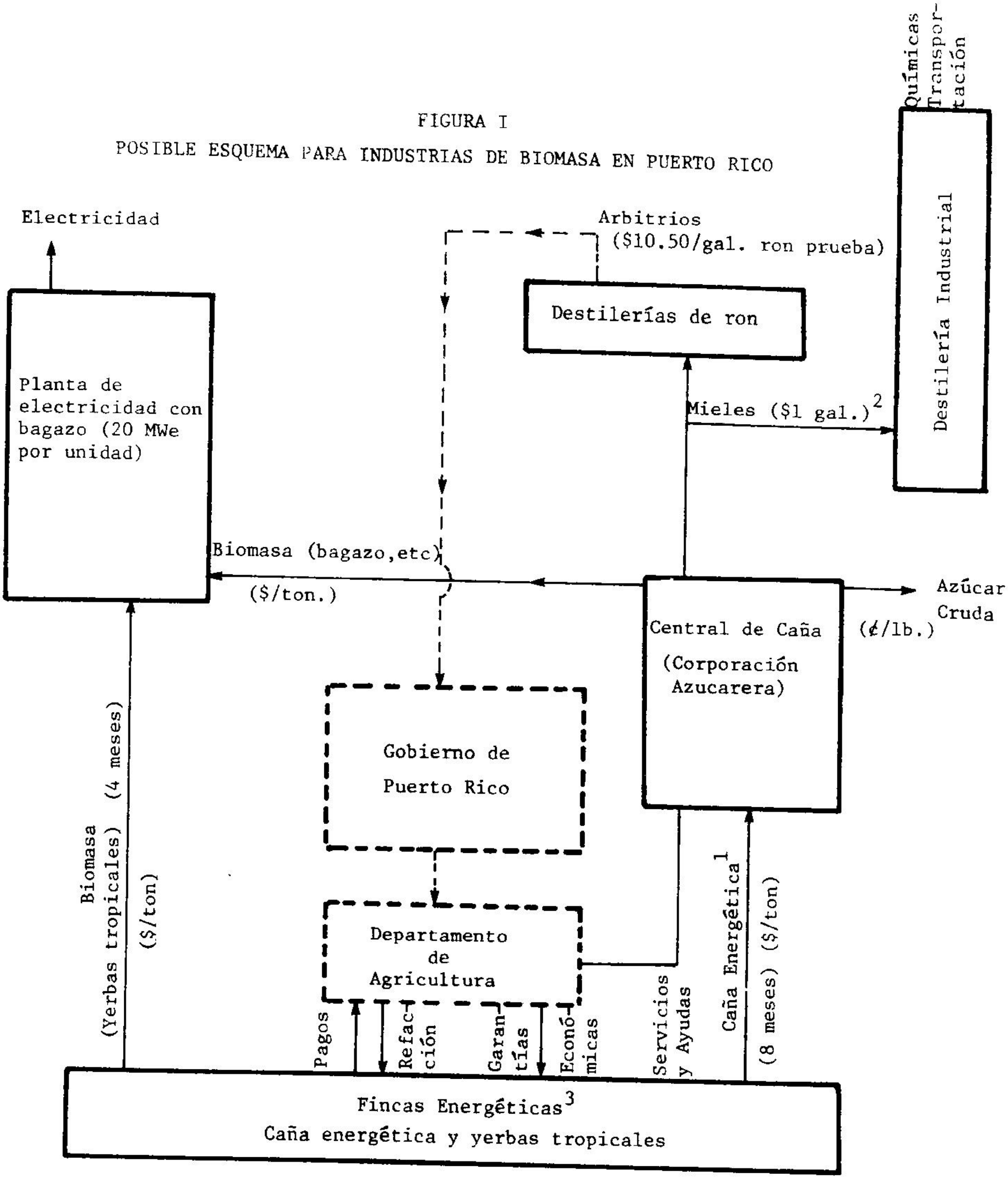
(e)= Estimado

Fuente : Referencia Número 4

FIGURA I

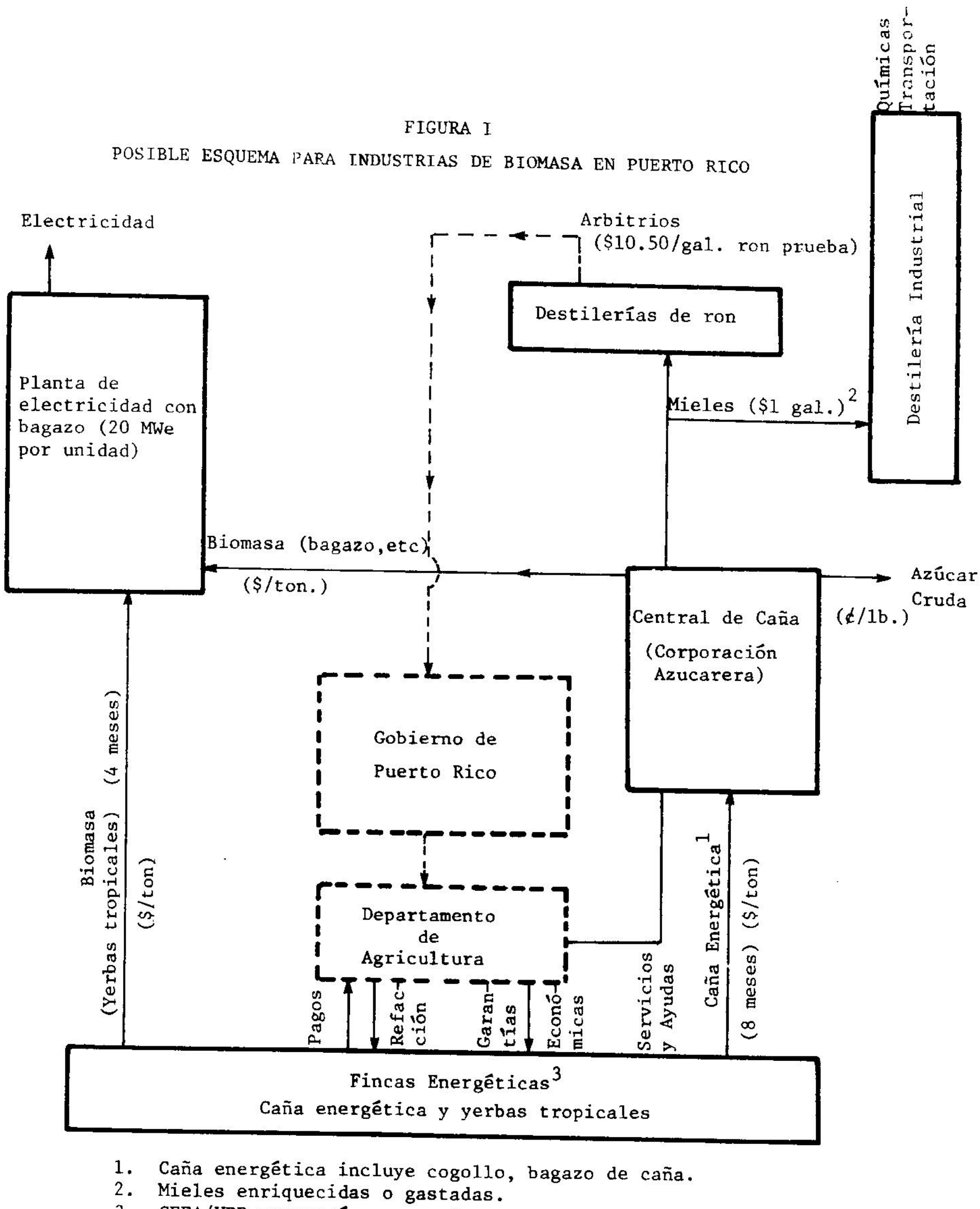
POSIBLE ESQUEMA PARA INDUSTRIAS DE BIOMASA EN PUERTO RICO



1. Caña energética incluye cogollo, bagazo de caña.
2. Mieles enriquecidas o gastadas.
3. CEEA/UPR proveerá asesoramiento.

FIGURA I

POSIBLE ESQUEMA PARA INDUSTRIAS DE BIOMASA EN PUERTO RICO



1. Caña energética incluye cogollo, bagazo de caña.
2. Mieles enriquecidas o gastadas.
3. CEEA/UPR proveerá asesoramiento.

TABLE I

The Caribbean

Country & indep. date (or metrop.)	Popula-tion	Area (sq.km.)	Pop. Dens. (per sq. km.)	x106 US$ *GDP/GNP**	Per Cap. *GDP/GNP**US$
Anguilla (U.K.)	6,500	91	71	3.0*	461*
Antigua (1981)	77,226	280	276	79.1*	1,039*
Bahamas (1973)	209,505	13,940	15	1.0**	4,760**
Barbados (1966)	252,000	430	586	950.4**	3,817**
Belize (1981)	146,000	22,958	6	184.5**	1,200**
Bermuda (U.K)	72,000	53	1,350	598**	10,894*
Cayman Islands (U.K.)	17,035	259	66	72*	4,800*
Cuba (1902)	9,771,000	113,960	86	13,300*	1,360*
Dominica (1978)	74,100	749	99	49.7**	598**
Domin. Rep. (1844)	5,762,000	48,433	119	5,500**	990**
Grenada (1974)	107,000	344	312	50.2*	459*
Guadeloupe (France)	317,000	1,779	178	957*	3,040*
Guiana (France)	66,000	90,999	1	120*	1,935*
Guyana (1966)	795,000	214,970	4	560.7**	690**
Haiti (1804)	6,000,000	27,749	212	1,500**	288.6**
Jamaica (1962)	2,225,000	11,424	195	2,979*	1,339*
Martinique (France)	312,000	1,100	283	1,135*	3,559*
Montserrat (U.K.)	12,034	102	117	20**	1,736**
Neth. Antilles (Neth.)	243,000	992	244	864*	3,472*
St. Kitts/Nevis (1983)	44,404	269	165	48.1**	920**
St. Lucia (1979)	122,000	616	198	210*	1,696*
St. Vincent (1979)	115,000	388	296	59**	513**
Suriname (1975)	388,000	163,758	2	822.4**	2,370**
Trinidad/Tobago (1962)	1,176,000	5,128	230	5,700*	4,847*
Turks/Caicos (U.K.)	7,436	497	15	15**	2,000**
Virgin Isl. (U.K.)	12,244	153	81	28.5**	2,456**
Totals:	28,329,484	721,421		35,806.6	--
United States	226,504,825	9,372,623	25	2,626,100**	11,536**
Puerto Rico	3,240,000	8,897	364	11,771**	3,001
U.S. Virgin Isl.	98,307	342	287	542**	4,743**

Source: Caribbean/Central American Action, Caribbean Databook, 1983; for the U.S.: U.S. Dept. of Commerce, Bureau of the Census, Statistical Abstract of the United States, 1981. The years in which these were measured vary. Some are at constant dollars. The figures are based on United Nations and national data.

TABLE 2

Selected Caribbean Countries

Commercial Energy Production and Consumption

1980 in TOEx10^3

Country	Production					Demand				
	Total	Oil	Coal	Gas	Elec.	Total	Oil	Coal	Gas	Elec.
Dominican Republic	14	-	-	-	14	1931	1917	1	-	14
Haiti	60	-	-	-	60	301	241	-	-	60
Jamaica	31	-	-	-	31	2150	2118	1	-	31
Trinidad/Tobago	13260	10760	-	2500	-	5872	3372	-	2500	-

Sources: The Energy Transition in Developing Countries, World Bank, 1983.

The Role of the Bank in Latin America in the 1980's, Interamerican Development Bank, April 1981.

TABLE 3

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

Island or Country	A (1) Installed Electricity Capacity (Megawatts)	B (1) Yearly Electricity Production (Millions of kwh)	C (2) Electricity Production Per Capita (EPPPC)(kwh/person)	D (3) Gross National Production Per Capita (GNPPC)(US$/person)	E (3) EPPC/CNPPC (kwh/US$)	F (4) Refinary Capacity thousands barrels/day
Antigua	26	53	716	950	0.75	18
Bahamas	255	675	3,096	2,620	1.18	500
Barbados	105	266	1,164	1,940	0.6	3
Colombia	3,850 d/	15,343	600	870 e/	0.68	162
Cuba	1,876	7,750	775	810	0.96	134
Curacao-Aruba	164	---	---	---	---	---
Dominica	6	16	208	440	0.47	11
Grenada	7	28	264	530	0.5	NA
Guyana	180	425	523	560	0.94	0
Haiti	102	276	57.5	260	0.22	0
Jamaica	705	2,130	1,014	1,150	0.88	33
Martinique d/	55	194	526	2,900	0.18	10
Mexico	12,847 d/	46,612 d/	696 d/	1,374.3 a/	0.51	509 d/
Monserrat	4	10 c/	787	920	0.85	0
Puerto Rico	4,207 b/	11,121 b/	3,502 b/	3,172 b/	1.10	189 f/
Dominican Republic	900	2,763	539	910	0.59	33
St. Kitts-Nevis	13	27	540	660	0.81	0
St. Lucia	15	50	417	630	0.66	0
St. Vincent	9	20	189	380	0.40	0
Trinidad & Tobago	1,454	1,640	1,442	2,910	0.5	431
Venezuela	6,119 e/	23,276 d/	1,666	2,910	0.6	1,453

References:

1. Energy Resources in the CDCC Member Countries, EL CEPAL/CDCC/65 28 May 80/Data 1978
2. From Column D. and B
3. Informe Sobre El Desarrollo Mundial, Agosto 1980 and columns C and D
4. (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 4

DEVELOPMENT AND POTENTIAL OF ENERGY RESOURCES IN THE CARIBBEAN

Island or Country	Oil and Gas	Coal	Hydro power	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
Haiti	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	5b	5c	5a
St. Kitts-Nevis	NA	NA	NA	NA	NA	NA	5a
St. Lucia	1a	1a	1a	3a	2a	4a	5a
St. Vincent	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 (US)	1a	1a	1a	2a	2a	5a	5a

POTENTIAL

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

NA - Not Available

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, Organizaciones de las Naciones Unidas

TABLE 5

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 (50-100KW)	UN Interim-Fund
	2. Renewable Energy-Wind	Wind Generators (13KW)	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/TEU
	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	Brazil
	7. Renewable - Wind	Wind Turbine	OLADE
	8. Renewable Energy-Geotherman	Investigations	OLADE

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
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 Lab.-NASA
	5. Renewable Energy-Biomass	Biomass from Sugarcane and Tropical Grasses	DOE
St. Kitts-Nevis	1. Electricity	Generation and Transmission Development	CDB
St. Lucia	1. Electricity Generation	Generation Expansion	CDB
	2. Renewable Energy-Wind	Wind Power System	CDB
	3. Renewable Energy-Wind	Wind Power Chilling	Privetely
	4. Renewable Energy-General	Demonstration Facility	CDB
	5. Geothermal Energy	Geothermal Assessment	IEB
St. Vincent	1. Hydro	Hydro Development	CDB/BDD
	2. Renewable Energy-Biomass	Biogas Production from arrowroots	CDB
	3. Renewable Energy-Wind	Wind Power System	CDB
	4. Renewable Energy Biogas	Biogas Plant	EDF
Trinidad	1, Renewable Energy-Solar	Air Conditioning	---
Venezuela	1. Renewable Energy-Wind	Photovoltaic Project	Ministry of Energy and Mines

DATA FROM:

International Bank for Reconstruction and Development
June 9, 1981

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Grenada	1. Hydro	Hydrological Resources Assessment	Venezuela
	2. Hydro	Micro-Hydro Identification	OLADE
	3. Renewable Energy-Biogas	Biogas Unit Comparison	OLADE
Guyana	1. Renewable Energy-Biomass	Technical Assistance, Ethanol Production	Brazil
	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 Manufacturing	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	Charcoal Project	IDB
	7. Renewable Energy-Biogas	Biogas Demonstration Unit	OAS
	8. Renewable Energy-Solar	Solar Component in the Regional Program	USAID/CDB