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RENEWABLE ENERGY TRENDS AND OPPORTUNITIES IN THE CARIBBEAN

Prepared for the Joint Meeting of

The Human Settlements and Energy Project of the Organization of American States and the Economic Affairs Secretariat of the Organisation of East Caribbean States

St. John's, Antigua

October 19, 1983

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

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Wallace C. Koehler, Jr.

Center for Energy and Environment Research
G.P.O. Box 3682
San Juan, Puerto Rico 00936

The purpose of this paper is two fold. The first is to give a brief introduction to the Center for Energy and Environment Research, to outline its interests and capabilities. The second is to describe our view of energy issues in the Caribbean, explain what we have done, and explore what we consider some of the options to be.

A. A brief discussion of CEER

CEER was established in 1957 as the Puerto Rico Nuclear Center. For a decade and a half, the Nuclear Center undertook nuclear research and provided training for scientists and students from throughout Latin America.

Following the energy crises of the early 1970's, the decision was taken to redefine the role of the Center. As a consequence, a new entity was created in 1976, CEER, to focus on energy and environmental issues.

In order to fulfill that role, CEER is divided into two sections: Energy and Environment. Each of these is further divided into divisions which focus on more specific aspects of the problem area. To further meet its mission, CEER undertakes basic research as well as development and demonstration. In addition, because science and technology, energy and the environment are so inextricably tied to social and economic issues, CEER maintains staff expertise in those areas as well.

Moreover, CEER as a part of the University of Puerto Rico serves as a manager of expertise for the University as well for the scientific and technical community of the Island. Through both its own and its University association, CEER participates in a number of important Caribbean and non-Caribbean organizations. These include the

Association of Caribbean Universities and Research Institutions (UNICA) and Oak Ridge Associated Universities (ORAU).

CEER's experience lies in Puerto Rico, the Caribbean and Central America. Our work has included much research into renewable energy alternatives. These include extensive research into OTEC, wind, biomass and solar energy in the Region. We believe we are among the foremost in development of energy systems and strategies for small to medium size tropical islands. Likewise CEER has developed extensive expertise in the marine and terrestrial ecologies of those same areas. We believe this expertise to not only be useful for the Caribbean, but for other tropical islands - for example those found in the Pacific and Indian Oceans -as well.

B. <u>Introduction</u>

The 51 inhabited islands of the Caribbean archipelago have a total land area of about 230,000 square kilometers and a total population of approximately 20 million. It is a complex region, strategically located, with a diverse ethnic, cultural and political base. It is a mosaic not only of independent states but entities having varying relationship with the United States and European powers.

The Caribbean community has a very rich potential in inexhaustible alternative energy sources. In addition to geothermal energy, which is abundant in locations such as St. Lucia, many feasible inexhaustible solar-related alternative energy sources exist. This is largely due to the fact that the Caribbean, lying between latitude 10°N and 25°N, has a resulting year-round solar insolation of approximately 2000 BTU per square foot per day. A few of the more common of the solar-related resources are trade winds, ocean waves, moderate ocean currents, extensive ocean thermal masses, year-round biomass production, agriculture, and mariculture. Table 1 summarizes geographic, demographic and other data on the Caribbean region. Only one of these island-states produces fossil fuels. This is Trinidad and Tobago, which has 1/45th of the land area and 1/20th of the population. The other 50 island-communities depend on imported fossil fuels for 99% of their energy requirements. It has been estimated that almost 38 million barrels of oil per year are imported by these islands valued at over one billion dollars.

Since the 1950s, the Caribbean has made strenuous efforts to diversify its economy by providing more jobs through industrialization and by expanding tourism. As in so many developing countries throughout the world, these early efforts were almost totally based on the use of imported fossil fuels. By the end of the 1980s most of the archipelago could face serious problems unless the dependence on imported fossil fuels is reduced and the use of alternative sources of energy is greatly increased. Six of the more important obstacles to progress are:

1. shortage of trained personnel to undertake a) energy assessment and b) to develop alternative energy programs;

2. inadequate research in the use of existing technology and adaptation or modification of the various technologies to the social and physical environment;

3. the absence of organized markets for indigenous, renewable fuels thereby limiting their ability to replace imported fuels;

4. the lack of investment capital;

5. a reluctance of national governments to consider regional cooperative efforts as well as a lack of non-governmental networks among the private sector, universities, and research institutes

6. the subcritical size of most Caribbean national energy systems precludes multiple solutions and sometimes even to choice of solutions.

A system of cooperation is of great importance in a region whose history has been one of fragmentation and dependence on external markets and external authority. A long history of dependence on external rulers has left many of the Caribbean peoples a bitter legacy of resentment, even of hatred. The ideological conflicts that characterize the contemporary Caribbean are evidence of this, just as the boat people from Cuba and Haiti and the illegal immigration into Puerto Rico from the Dominican Republic are indicators of growing poverty and discontent. Aid from the industrialized countries is important, but it cannot of itself provide a solution. Caribbean development depends, in the last resort, on the capability of the Caribbean people to analyze their problems and, with assistance from others, to find solutions for them.

Because of the urgency of the energy situation in the Caribbean, it is crucial to the orderly economic and cultural development of the region that a degree of energy self-sufficiency be developed at an early date. If this does not occur, disastrous consequences will result as the price of imported fuel escalates beyond the reach of all but the most well-endowed (or most heavily subsidized) communities, thus forcing them into either a position of complete dependence on those who have oil, or into a position of extreme poverty, beyond which economic and political survival may become impossible.

C. Reduction of Energy Dependence

Let us acknowledge at the outset that there are no quick fixes, but that there are important opportunities. Our first responsibility is to develop technologies and policies for oil substitution and conservation. Imported oil is used to fire 98% of electrical generation and provides virtually all liquid fuels consumed in the transport sector. At the same time, the Caribbean region possesses an array of potential renewable sources of energy. These resources may contribute to the energy equation in Caribbean as well as reduce balance of payments problems. Moreover, many are inherently "small-scale" or can be so applied, and therefore are not effected by the economies of scale and shift in dependencies associated with nuclear and coal.[1]

The following explores eight renewable technologies and their application in the Caribbean:

1. Geothermal Power

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. Vincent, the 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 indicated that for Dominica extensive surface manifestations make the geothermal potential 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 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.

2. Solar Energy

Solar Energy as an alternative source of energy has received the greatest attention in recent times. The solar radiation in the Caribbean Region is on the order of two thousand kilowatt hours per square meter per year. Presently, solar energy is used on a very limited scale in the Caribbean for crop drying, water purification, heating and distillation. Solar stills have been built by a foreign research institutes, for example, one in Haiti and one in St. Vincent. 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.

A survey undertaken in January 1982 by CEER, in conjunction with the Puerto Rico Department of Labor and Human Resources, indicated that there were approximately 18,000 residential hot water heaters in use on the Island. The development of solar industrial steam generators and solar air conditioner units is also being pursued. A 1,100 square meter solar air conditioned factory in Canovanas, Puerto Rico, and a new 400 square meter solar air conditioned Post Office in Guayama, Puerto Rico, are examples of commercial installations. In Lagos del Norte, a 203-apartment condominum in Toa Baja, Puerto Rico, 3860 sq.ft. of solar collectors were installed, with a 2500 gallon hot water tank to supply the needs of the more than 1000 residents.

Also in Puerto Rico a 240 sq.ft. shallow solar pond system has been designed for hot water generation and storage for a high school in Mayaguez by CEER which has also developed a salt gradient pond computer design. Also in Mayaguez, CEER is currently installing a single stage cold generator designed to use hot water to reclaim refrigerant to sustain the refrigeration cycle. Over 300 parabolic trough collectors made of fiber glass, using boat technology, have been built, giving promise of great durability. In the Dominican Republic and on the island of Anguilla some applications of natural salt-gradient ponds are presently being considered for solar energy storage.

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 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 indsutry 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 collectors by unskilled labor is a good 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.

3. 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 it 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.

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. CEER had been actively working on the development of an OTEC project on the southeast coast of Puerto Rico. Its floating platform laboratory ran longer, continuously, than any other similar data-gathering station in the world at probably the best site for this purpose in the United States. That research has been suspended as a result of policy changes in Washington. We believe however that OTEC nevertheless has great potential in the Caribbean.

4. 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, Suriname and Jamaica. In Guyana, hydro potential of from 7,200 to 7,600 megawatts has been identified, and in Suriname 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. El Centro La Gaviota in Colombia has developed some mini hydro technologies suitable for the region.

5. 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., sugarcane.

Sugarcane is grown in many of the Caribbean countries and in large quantities in Barbados, Cuba, the Dominican Republic, Guyana, Haiti, Jamaica, Puerto Rico, St. Kitts-Nevis, Anguila, and Trinidad and Tobago. Sugar factories in Haiti are able to satisfy 100% their energy requirements from bagasse and 90 percent of their energy requirements in Barbados. 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 Haiti's total primary energy supply.

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 the CEER in cooperation with the 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% 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 is 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 the Puerto Rican rum industry (80%) dependence on imported molasses, and reduce Puerto Rico's petroleum imports by 17%.

Studies currently suggest that costs would approximate about $1,000 to $1,100 per acre and yield fiber and molasses product valued in excess of $3,000 per acre. 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 $2.00 per million BTU.

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 60°F. There are literally thousands of plant species, both woody and herbaceous, capable of utilizing this climate for continuous growth processes. Approximately 80% 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.

6. 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 kilojoules 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 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 one assumes 30 millions broilers, the energy potential equivalent to the methane produced will be 3 million kilowatt hours per day.

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 24.6 tons of raw manure 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 proposed energy-integration complex consists of eight subsystems. These include components for manure preparation and blending, a biogas generation subsystem, 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 3.5 million gallon anaerobic digester tank to treat their distillery residue wastes before dumping them into the ocean.

Disposal of municipal wastes becomes an increasigly 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.

7. Wind

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 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 Puerto Rican island of Culebra. This energy machine produced 584,990 KwHr 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. Although the residents favored wind energy as an alternative in Culebra, 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 Rockefeller 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.

D. Technology Transfer

Much is known of various renewable technologies. Yet this knowledge may be of little value if it is not or cannot be transferred from one society to another. There are many vehicles for technology transfer, ranging from the training of foreign nationals in one's universities to the outright purchase of turn-key plants.

In closing I want to discuss two systems employed or proposed at CEER. We believe there exist numerous centers of excellence in renewable energy in the Caribbean. UNICA's Commission on Science and Technology (chaired by CEER's Director Dr. Juan A. Bonnet, Jr.) identified the three renewable technologies deemed most likely to undergo near term development. These three are wind, biomass and solar. Three centers of excellence were identified and workshops were held in Bridgetown, Barbados (wind), San Juan, Puerto Rico (biomass) and Gainesville, Florida (solar). University faculty, energy specialists and government officials participated and were familiarized with the state-of-the-art[2]. A constant interaction of this kind would do much to educate one another in potential applications of renewable technology.

Second, CEER has proposed a satellite link in the Caribbean as a pedagogical device. A linkage among libraries could provide researchers, students, and scholars access to a much wider range of information[3]. That has obvious implications for the dissemination of energy information.

E. Conclusion

There are many differences among the Caribbean islands, yet there are answers and experiences to benefit them all. With the exception of one, all are heavily dependent on imported oil for their electrical, industrial and transport sectors. Renewable energy technologies, shared among all could contribute significantly to a reduction of that dependency and provide new stimulus to economic development.

FOOTNOTES

1. See e.q. M.B.A. Crespi, "La Energía Nuclear en América Latina- Necesidades y Posibilidades" Interciencia 4, 1 (1979) pp 22-31 and V.J. Huacuz M., "El Debate Nuclear, Sus Implicaciones en América Latina" Interciencia 2 (1977) pp. 264-72.

2. Juan A. Bonnet, Jr. and Wallace C. Koehler, Jr., "Development of Alternative Energy Science and Engineering in the Caribbean" II Simposio Interuniversitario de Energía, Santiago de Chile, November 1983.

3. Juan A. Bonnet, Jr. and Modesto Iriarte, Jr., "Perspectivas para una Red de Comunicaciones de Enlace Vía Satélite entre las Universidades de Latinoamérica y del Caribe" Interciencia 8,5 (Sept-Oct. 1983) pp 284-288.