CEER-X-175, "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.

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The purpose of this paper is twofold. 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 1970s, 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 hub of expertise for both the university and the scientific and technical community of the island. Through its own initiatives and its association with the university, 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 extends to Puerto Rico, the Caribbean, and Central America. Our work has included extensive research into renewable energy alternatives such as OTEC, wind, biomass, and solar energy in the region. We believe we are among the leaders in the development of energy systems and strategies for small to medium-sized tropical islands. Similarly, CEER has developed extensive expertise in the marine and terrestrial ecologies of these islands. We believe this expertise is useful not only for the Caribbean, but also for other tropical islands, for example, those

found in the Pacific and Indian Oceans.

B. Introduction

The 51 inhabited islands of the Caribbean archipelago, with a total land area of about 220,000 square kilometers and a total population of approximately 20 million, form a complex and strategically located region with a diverse ethnic, cultural, and political base. It is a mosaic not only of independent states but also entities having varying relationships 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 solar-related resources are trade winds and ocean waves.

Moderate ocean currents, extensive ocean thermal masses, year-round biomass production, agriculture, and mariculture are some of the key features of the Caribbean region. Table 1 summarizes the geographic, demographic, and other data on this region.

Out of all the island-states, only Trinidad and Tobago produces fossil fuels. Despite representing only 1/45th of the land area and 1/20th of the population, it plays a significant role in the region's energy sector. The remaining 50 island-communities rely on imported fossil fuels for 99% of their energy requirements.

It is estimated that nearly 38 million barrels of oil are imported by these islands annually, valued at over one billion dollars. Since the 1950s, the Caribbean has made extensive efforts to diversify its economy, providing more jobs through industrialization and expanding tourism. However, like many developing countries worldwide, these early efforts were almost entirely based on the use of imported fossil fuels.

By the end of the 1980s, it became clear that most of the archipelago could face serious problems unless the dependence on imported fossil fuels is reduced, and the use of alternative energy sources is significantly increased.

Six of the more critical obstacles to progress are:
1. A shortage of trained personnel to undertake a) energy assessment and b) develop alternative energy programs.
2. Inadequate research in the use of existing technology and the adaptation or modification of various technologies to suit the social and physical environment.
3. The absence of organized markets for indigenous, renewable fuels, thereby limiting their ability to replace imported fuels.
4. A 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 the 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 has a long history. In many Caribbean communities, this dependence on external rulers has left a bitter legacy of resentment and even hatred. The ideological conflicts that characterize the contemporary Caribbean are evidence of this. Indicators of growing poverty and discontent can be seen in the boat people from Cuba and Haiti, as well as the illegal immigration into Puerto Rico from the Dominican Republic. Aid from industrialized countries is important, but it cannot provide a solution in itself. Ultimately, Caribbean development depends on the ability of the Caribbean people to analyze their problems and, with assistance from others, find solutions for them.

The energy situation in the Caribbean is urgent and it is crucial for the orderly economic and cultural development of the region to achieve a degree of energy self-sufficiency at an early date. If this doesn't occur, disastrous consequences will result as the price of imported fuel could escalate beyond the reach of all but the most well-endowed (or most heavily subsidized) communities. This could force them into a position of complete dependence on those who have oil, or into extreme poverty, where economic and political survival may become impossible.

C. Reduction of Energy Dependence

Let's acknowledge at the outset that there are no quick fixes, but there are important opportunities. Our first responsibility is to develop technologies and policies for oil substitution and conservation. Imported oil is used to generate 98% of electricity 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 could contribute to the energy equation in the Caribbean and also reduce balance of payment problems. Moreover, many of these resources are inherently "small-scale" or can be so applied, and therefore are not affected by the same issues as large scale operations.

Economies of scale and shifts in dependencies associated with nuclear and coal are currently being explored. The following text delves into eight renewable technologies and their application in the Caribbean.

1. Geothermal Power: Volcanoes 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 have been ordered. Reports of potential geothermal energy resources have been made in Dominica, Montserrat, St. Lucia, St. Vincent, the Dominican Republic, Grenada, Haiti, and Jamaica. 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. As for Haiti and Grenada, it will be necessary to determine the origin of the hot springs to ascertain whether they are geochemical or geothermal before any exploratory drilling can be attempted. A feasibility study of geothermal potential is currently underway for the generation of electricity in the Dominican Republic.

Geothermal energy does have some environmental disadvantages as 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 have been in California, New Zealand, Mexico, and Central America.

2. Solar Energy: Solar energy as an alternative source of energy has received significant 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. Currently, 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 foreign research institutes. For example, there is 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 constructed 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 condominium 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. CEER has also developed a salt gradient pond computer design. 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 fiberglass, using boat technology, have been built, promising 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

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An example of this is the Technical Energy Unit (TEU) building of the Caribbean Development Bank (CDB). Testing of this passive system is in progress. Additionally, two solar air conditioning systems have been installed and are 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 $8.5 million. The largest solar hot

water system in the Caribbean opened in September 1981 at the Cornwall Regional Hospital in Jamaica. This project was sponsored by the Citizens Energy Corporation.

The Caribbean has almost everything in its favor to make solar industrial energy a success. It boasts 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, and 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 technology, they would either do it in the most favorable economic environment, or at the location where they have the most 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.

Ocean Thermal Energy Conversion (OTEC) is a potential source for commercial supplies of electrical energy. 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 KWH per year. Strong ocean surface currents are also a significant factor.

The text flows through the Caribbean Sea from the Atlantic and continues to gain speed through the Yucatan Channel. The main current moves at an average velocity of approximately one mile per hour. Notably, temperature gradients between the ocean surfaces and depths of 1000 meters exceed 22°C (40°F). These currents and temperature gradients are great untapped energy sources. The Caribbean Sea's maximum depth is 6,150 meters, located approximately 160 kilometers south of Puerto Rico in the Muertos Trough. However, depths of 1000 meters are found two kilometers southeast of Puerto Rico. CER has been actively developing an OTEC project on Puerto Rico's southeast coast. Its floating platform laboratory has operated longer and more continuously than any similar data-gathering station worldwide, likely making it the best U.S. site for this purpose. Unfortunately, this research has been suspended due to policy changes in Washington. Nonetheless, we believe that OTEC holds significant potential in the Caribbean.

4. Hydropower

Hydropower plays a critical role in Dominica, Haiti, and the Dominican Republic. It supplies 90 percent of Dominica's power and 27 percent of the Dominican Republic's. Hydropower could also be important in Guyana, Suriname, and Jamaica. In Guyana, a hydro potential of 7,200 to 7,600 megawatts has been identified, and Suriname has a hydropower potential of 3000 megawatts. Belize is interested in mini hydro projects. A Colombian engineering firm is providing technical support to Haiti and Dominica to develop small-scale hydroelectric resources. El Centro La Gaviota in Colombia has developed mini hydro technologies suitable for the region.

5. Biomass

Broadly speaking, biomass consists of terrestrial and aquatic vegetation, its residues and wastes, including animal wastes. Biomass is essentially a renewable and indirect form of solar energy, with sunlight powering the chemical reaction that converts CO2 and water into solid green matter.

Water and oxygen are crucial. 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, namely,

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% of their energy requirements from bagasse, and 90 percent of their energy requirements in Barbados. Bagasse is also used extensively as fuel for sugar mills 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 ongoing 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. The optimization of tropical grasses for biomass production has also been studied.

A short ton of "oven-dry" biomass (with 68% moisture) contains about 15 million BTUs of energy. This is equivalent to two 82-gallon barrels of residual fuel oil. In addition, a significant amount of sugar and high-test molasses are also produced.

CEER scientists have estimated that 70,000 acres planted in energy cane could produce yields roughly doubling present sugar production, eliminate entirely the Puerto Rican rum industry's 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 summary, despite inflation and rising labor and other costs, the potential benefits are significant.

It is currently possible to plant energy cane in Puerto Rico and produce it for less than $2.00 per million BTU. Puerto Rico, geographically and historically Caribbean, is well-positioned to establish a biomass energy industry. Located approximately 18° north latitude, its tropical climate supports year-round plant growth. Temperatures rarely drop below 60°F. The region boasts thousands of plant species, both woody and herbaceous, that can utilize this climate for continuous growth processes.

Approximately 80% of the land mass is humid, receiving abundant rainfall, while irrigation is well-developed in the remaining arid regions. The island is divided into six distinct ecological life zones. The varied landscape provides a wide selection for both research and commercial development. Puerto Rican soils are categorized into 9 orders, 27 suborders, 37 great groups, 64 families, and 163 series, representing nearly all the Caribbean in its variety.

Bioconversion biogas is produced when organic wastes, manure, vegetable matter or human waste decompose under anaerobic conditions, such as those found in an airtight digester. The biogas produced typically contains 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 ceases in the digester, the residue forms an excellent fertilizer which can be used to grow algae. The liquid can be extracted for irrigation. A 1,200 pig farm, operating successfully in the south of Puerto Rico, runs entirely on local biogas production. Algae is also grown there as a feed supplement for the pigs. It has been estimated that the manure from one large dairy cow could yield 2.5 cubic meters of biogas per day.

The text is roughly equivalent to one-third of a gallon of gasoline per day. It has been estimated that waste from one thousand poultry broilers is capable of producing about 10 cubic meters of methane. If one assumes 30 million 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 currently has a milking herd of 500 registered Holsteins. In 1982, the farm's average power demand was about 1,680 kWh per 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. The integrated system will provide from 30 to 80 percent of dairy feed requirements and 60 to 80 percent of farm power needs. 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 is an increasingly serious problem every year due to 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. The northeast trade winds prevail over the Caribbean sea.

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 kWh of energy from 1978 to 1981, despite downtime to improve blade performance and despite the occurrence 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 windmill'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

The outright purchase of turn-key plants is a topic I'm closing on. I want to discuss two systems employed or proposed at CEER. We believe there are 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 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. 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. 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 the reduction of that dependency and provide new stimulus to economic development.

FOOTNOTES

1. See e.g. M.B.A. Crespi, "La Energia Nuclear en América Latina Necesidades y Posibilidades" Interciencia &, 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" at Simposio Interuniversitario de Energia, Santiago de Chile.