

DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE  
AND ENGINEERING IN THE CARIBBEAN

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### DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE AND ENGINEERING IN THE CARIBBEAN

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Abstract. This paper describes a pilot project designed to improve the capabilities of Caribbean universities and research institutes in helping solve the energy problems of the region. Most of the region is almost completely dependent on imported petroleum to satisfy its energy needs. That dependency has exacerbated economic problems with the escalation of petroleum prices in the past ten years. A potential solution to reduce both the high degree of dependence and economic costs is to develop other energy systems. The region is blessed with solar, wind, ocean, biomass, and geothermal resources that could be exploited to reduce and displace oil consumption.

One approach is to develop the scientific and engineering capabilities of regional universities. Under the auspices of the Association of Caribbean Universities and Research Institutions (UNICA) a project to foster cooperative research efforts to assist in the introduction of alternative energy solutions has been developed.

The UNICA project utilized the research workshop format. A network of scientists and engineers working in energy was established to promote cooperation, interchange of technical information and development of joint projects. Three workshops were convened on the most promising energy alternatives: wind energy in Barbados in December 1981; tropical biomass in Puerto Rico in April 1982; and solar energy utilization in Florida in June 1983. In each of the workshops a list of needs and priorities in education and training, research and development, and demonstration projects was worked out and are discussed in this paper. Basic energy data on Caribbean Basin countries was collected in order to perform system analysis of energy alternatives. The project has already stimulated technological interchanges in the region.

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## A. Introduction

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 ethoric, 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, which has 1/45th of the land area and 1/20th of the population. The size of its foreign exchange reserves places it among the first six of all the nations in the British Commonwealth. The other 50 island-communities depend on imported fossil fuels for 99% of their energy requirements. It is estimated that 37,950,000 Bbls. of oil per year are imported by these islands.

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 will be a potential disaster area unless the dependence on imported fossil fuels is reduced and the use of alternative sources of energy is greatly increased. Four of the major obstacles to progress are: (a) lack of manpower; (b) inadequate research in the use of existing tech-

nology and adaptation or modification of the various technologies to the social and physical environment; (c) lack of a grass roots cooperative energy program involving the universities and research institutes of the region; and (d) lack of investment capital.

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. Cooperative relationships between individual United States and Caribbean universities, though valuable in themselves, do not fully meet the need for transforming donor-recipient relationships into a large partnership of scholars and scientists.

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.

The universities and research institutes of the Caribbean region constitute an important under-utilized resource of knowledge, expertise and institutional facilities. This resource is under-utilized largely because (a) the region is not looked upon as a whole; (b) because there is little communication among the scientists of the region; (c) and

because the Caribbean community does not perceive its universities as being intimately involved in the development process. Yet a great deal of valuable work is being done in its universities and research institutes. Consequently it is essential that Caribbean universities and research institutes should be utilized to their fullest to achieve greater self sufficiency in basic necessities such as energy and food.

The Association of Caribbean Universities and Research Institutions (UNICA) has sought to provide a forum of cooperation necessary to develop solutions to the problems of energy in the Caribbean. To do so UNICA has launched a program to foster cooperative research effort aimed at assisting in the introduction of alternative energy solutions.

This project provided for and depended upon the active cooperation of universities and research institutes from the Spanish, English, French, and Dutch speaking Caribbean. The levels of research work varied, and required the more advanced centers to provide technical assistance to those which are less advanced. In this way the effort to find viable programs for the use of alternative sources of energy was shared by all the institutions involved. The project attempts to make full use of a network of Caribbean institutions, providing a mechanism for training at appropriate centers within the region, and involving many participants in research programs and in the preparation of a comprehensive regional program for using alternative sources of energy. Through this method, the quality of science and engineering research was improved, and the potential for stimulation for technology transfer and for further cooperative efforts were realized.

The project focused on the need for the countries of the Caribbean archipelago to achieve greater self-sufficiency in energy; on the role that Caribbean universities and research institutes can play in meeting this need; and on the fact that the region has a rich potential in inexhaustible alternative sources. It represents the first indispensable step in using the existing network of research centers, schools of natural sciences and engineering, and other related university departments in a coordinated program to help meet the region's energy needs. Furthermore, it points the way to an exciting concept of the region as a laboratory for the development of alternative sources of energy, in

which lessons can be learned and demonstrations carried out that will be of benefit to other countries that have similar needs.

## B. Development

The objective of the project was to develop and extend the scientific and engineering capability of Caribbean universities and research institutes so that they will be able to contribute effectively to the wider use of alternative sources of energy in the region.

### 1. Mechanism for Achievement

#### a. The Association of Caribbean Universities and Research Institutes (UNICA)

In the late 1960s, perceptive Caribbean educators saw the future development of the Caribbean community as a matter of regional concern. To meet their common needs they created UNICA, a voluntary association of Caribbean universities and research institutes dedicated to positive, carefully directed efforts for Caribbean development. Founded in 1968 by 16 universities located in ten Caribbean countries, the organization now has 45 member institutions representing a constituency of more than 300,000 students and 30,000 faculty.

### 2. Expected Significance

The success of the project has had a profound effect on the creation of a program to develop economic independence and energy self-sufficiency within the Caribbean. And that should lead to greater social and economic progress. The Caribbean may thus serve as a model of the benefits which can accrue through the development of the local scientific and engineering capabilities of regional universities as they work together to solve problems of immediate national and regional significance.

### 3. Project Description

#### a. Overview

The project, limited in time and specificity of its purposes, represents the first important step toward a major coordinated program of research and technology adaptation to be undertaken by the universities and research institutes of the region.

The work was carried out in three phases. The first phase involved planning activities, identification of UNICA institutional contact persons and background literature searches. The second phase involved the holding of three workshops dealing with various aspects of the alternative energy problem: on wind, biomass and solar utilization. The third phase involves the completion of research plans and proposals resulting from the workshops, the preparation of education and manpower training plans, and the compilation of reports on the alternative energy data base and organization which has been generated. Funding for this project came from grants from the U.S. National Science Foundation and the Exxon Education Foundation.

b. Procedure

1. Phase One

Phase One of the project consisted of all planning activities. The steps completed in Phase One included:

(1) Appoint members of the UNICA Commission on Science and Technology and receive their agreements to serve. This was completed before June 1980 and the following persons agreed to serve:

- \* Dr. Erich Farber, Director of the Solar Energy Institute, University of Florida, Gainesville.
- \* Professor Gerald Lalor, Pro-Vice-Chancellor of the University of the West Indies, Kingston, Jamaica and Head of the Department of Chemistry.
- \* Dr. Juan A. Bonnet, Jr., Director of the Center for Energy and Environment Research of the University of Puerto Rico.
- \* Eng. Francisco Gutiérrez, Director of the Institute of Petroleum, Central University of Venezuela.
- \* Dr. Howard P. Harrenstien, Civil Engineering Department, University of Miami.

(2) Convene a meeting of the UNICA Commission on Science and Technology and discuss the need for a cooperative program of alternative energy science and engineering research and education for the Caribbean. Prepare an outline draft of a plausible workshop plan.



(3) Contact all UNICA member universities and ask their chancellors or presidents to appoint university faculty liaison representatives to work on the alternative energy program. In order to implement the project this Commission requested from the universities and research institutes which are members of UNICA to appoint official contact persons knowledgeable in energy matters who could provide information on the energy state of affairs of their respective islands, participate in workshops, and serve as a focus to initiate educational and research activities in their institutions. A questionnaire was circulated to all UNICA contact persons and two follow-up notices were sent to assure maximum response. This experience reflected the reality of lack of information about energy and renewable energy matters in the Caribbean. After a search in general and specialized libraries and other information centers in the Caribbean, it was found that the best data were available at the Caribbean Development Bank in Barbados, the Island Resources Foundation in the Virgin Islands and the Center for Energy and Environment Research in Puerto Rico.

(4) Convene various meetings of the UNICA Commission on Science and Technology in conjunction with the November 24-25, 1980, Center for Energy and Environment Research - organized Symposium on Alternative Domestic Energy Systems for Puerto Rico, and the December 15-17, 1980 Clean Energy Research Institute-organized Third Miami Conference on Alternative Energy. At these meetings, prepare a questionnaire on alternative energy to be completed by the UNICA faculty liaison representatives.

(5) Receive and compile the results of the questionnaires at CEER. This activity was completed and resulted in the paper "Energy Alternatives for the Caribbean". The paper represents the most up to date general description of renewable alternative energy projects and potential in the Caribbean and constitutes a major contribution of this project.

Phase One activities were conducted primarily in San Juan, Puerto Rico and Miami, Florida, using the facilities of CEER and the Clean Energy Research Institute (CERI) respectively.

## 2. Phase Two

Phase Two consisted of the organization and conduct of three alternative energy workshops. Attendance at all workshops was by invitation only, and consisted of the UNICA contact persons, the UNICA Science and Technology Commission members, and invited industrial and investment representatives, key liaison faculty from supporting universities, involved faculty from the region who are known to be active in alternative energy research, and selected governmental personnel. Assignments were issued in advance, and the workshops were held in the vicinity of the most suitable places for demonstrations of viability and feasibility of the concept. The three workshops were concerned with:

- (1) Wind as an Energy Alternative for the Caribbean
- (2) Biomass as an Energy Alternative for the Caribbean.
- (3) Solar utilization.

The subjects were carefully chosen to emphasize those technologies which show the most promise of being cost-effective in short term. The choice also drew on the Puerto Rico experience in developing an understanding of the most viable energy alternatives. A paper was prepared titled "Alternative Energy in the Caribbean."

Each workshop was planned following the project needs and host institution capabilities but each contained certain essential aspects, or areas of emphasis. In general, these areas were:

- (1) State of the art in the particular technology,
- (2) Estimates of the magnitude of achievable resources,
- (3) Identification of barriers to commercialization,
- (4) Socio-economic considerations,
- (5) Plan for meeting science and engineering education requirements,
- (6) Identification of needs in basic research,
- (7) Time-frame for meaningful demonstrations,
- (8) Time-frame for maximum contribution to energy self-sufficiency,
- (9) Identification of sources of investment capital.

Wind was given first priority, as it is generally considered to be the most likely candidate as a short term cost-effective alternative energy source. Wind energy may be converted directly to mechanical en-

ergy and then to electricity without involving the Carnot cycle and the unavoidable thermodynamic losses which are associated with such energy conversion. In addition, the Caribbean is an area in which the trade winds are predictable and of sufficient magnitude to provide a reasonable level of power. It is logical to concentrate on this source as one which could provide an early payoff. The chances of early success should motivate and stimulate the growth of science and engineering capabilities in local universities, since needs for manpower training and local engineering capability should be quickly realized. Because of existing expertise and presence of the Caribbean Meteorological Institute and the Caribbean Development Bank, the wind workshop was held in Bridgetown, Barbados in December 1981.

Biomass was the second form of alternative energy considered since agriculture has traditionally been the principal source of income in the Caribbean. The year-round solar insolation, coupled with frequent rains on windward shores, provides one of the finest environments on earth for prolific biomass production. As imported fossil fuel prices rise, it is critical that this biomass potential be converted to clean-burning substitute fuels, such as methanol and ethanol. There is reason to believe that ethanol production from sugar cane is already cost-effective, particularly if attention is given to the productive use of wastes which are generated by the process. This second workshop was held in San Juan, Puerto Rico at CEER in April 1982.

The third and final workshop --solar energy utilization-- was held at the University of Florida, in Gainesville, in June 1983. This workshop's orientation was toward the completion of specific organizational and research plans, and the planning of cooperative projects. Gainesville is considered the Solar Capital of the World.

### 3. Phase Three

Phase three constitutes the reporting and implementation phase. The plan is to compile a narrative of the accomplishments of the project, and to report on the plans that individual institutions have made to enhance their science and engineering capabilities in support of alternative energy commercialization in their regions. This is underway at present.

It is anticipated that these plans will include mechanisms for demonstration and for training and education of the local manpower, in-

volving university faculty and students as resource personnel. It is also anticipated that this phase will solidify the interactive and cooperative nature of UNICA, with the result that growing trust and scientific and technological interchange among sister institutions will emerge.

This phase will also be used to finalize plans for continuance of similar types of activities into the future, being careful to build upon the experiences of the past and upon the capabilities which were acquired in the conduct of the initial project. Goals in basic research are to be identified, and recommendations made to granting agencies, industry, and financial institutions for the timely support of this research are to be identified, and recommendations made to granting agencies, industry, and financial institutions for the timely support of this research.

#### 1. Project Application Potential

A list of renewable energy technologies which are deemed technologically suitable for the Caribbean, in rank order of estimated commercial readiness, is as follows:

1. Solar hot water
2. Co-generation
3. Hydroelectric
4. Electricity from solid waste
5. Small wind machines
6. Large wind machines
7. Electricity from bagasse
8. Solar ponds
9. Photovoltaics
10. Ocean thermal energy conversion
11. Geothermal energy conversion
12. Other

The value of contribution in barrels of oil saved per year for each alternative energy technology at the end of full commercialization by the year 2000 has been calculated. This is presented in Table 2, where it can be observed that the combined contribution from the sources listed totals 154,230,000 Bbls. of oil saved per year. Consequently, the region could theoretically provide all necessary primary fuels for its electrical generation needs.

As is shown in Table 3, many technologies are undergoing research, development and/or demonstration in the Caribbean region. They range from off-shore oil exploration to geothermal to biomass. The table also demonstrate the wide range of donors or executing agencies, which include international and regional organizations, foundations and countries. The table also substantiates our conclusion that wind, biomass, and solar are appropriate alternative energy sources for the Caribbean.

### Workshop Summaries

#### 1. Wind as an Energy Alternative for the Caribbean Workshop

The first UNICA workshop was carried out in Bridgetown, Barbados on December 6-9, 1981. Some 50 persons participated. The first part of the workshop consisted of background papers on wind energy. Especially significant was the participation of Dr. T.S. Anderson, President of the USA Wind Energy Association, an organization which has a keen interest in the Caribbean. Following the general presentations, the participants were divided in three workshop groups addressing the following subjects:

- (1) Education and Training Needs
- (2) Research and Development Needs
- (3) Demonstration Needs

Each of the workshop session groups produced a report.

It is interesting to note that the recommendations are similar and that they focus on information needs and lack of human resources. A generalization and prioritization follows:

- (1) A resource assessment of human and institutional capabilities, wind resources, and demonstration projects in the region is needed.
- (2) After the first recommendation is implemented, detailed action plans and proposals to implement the other workshop recommendations are needed.
- (3) Sources of funding to continue this project and to implement the most important recommendations should be sought.

The group believes that if the above recommendations are implemented the scientific and engineering capabilities of the universities and research institutes in the region will be greatly enhanced and strengthened in wind as an appropriate energy source for the Caribbean region.

## 2. Biomass as an Energy Alternative for the Caribbean

The second workshop for UNICA contact persons was held in San Juan, Puerto Rico on April 28-29, 1982. It is significant that the same UNICA contact persons who attended the wind workshop were also able to attend this workshop. The liaison initiated among UNICA contact persons facilitated the establishment of direct contact between some of the UNICA member institutions.

This workshop was carried out immediately following the Seminar on Fuels and Feedstocks for Tropical Biomass II held in San Juan, Puerto Rico on April 26-27, 1982. Many of the UNICA contact persons were also able to attend this seminar, which provided them with more thorough knowledge of biomass as an energy resource.

The biomass workshops indicated that the group feels that:

- (1) Research, development and demonstration projects in biomass as an energy source must be established in the Caribbean region. Funding to carry out such projects is critically needed.
- (2) Provision of training and education on Caribbean tropical biomass is a must.
- (3) UNICA should increase its information dissemination and technology transfer activities in the region.
- (4) The role of the UNICA Foundation to secure funds to implement the recommendations of workshops is very important.

The Caribbean agricultural programs, especially in sugar cane and other food crops, are undergoing great economic stress. The possibility of a reorientation to biomass for energy and food combined is an alternative that must be pursued immediately. This is one of the main reasons for recommendation number one. The group feels that the only

reason this energy alternative is not being developed faster is lack of funding.

### 3. Solar Energy Utilization

The third workshop was held June 6-10, 1983 at Gainesville, Florida.

During this workshop the basics of solar energy conversion and utilization were covered and expanded to specific problems found in the Caribbean Basin. Presentations on solar radiation measurements and modeling in the Caribbean, Heat transfer, materials, collectors, applications of solar thermal, dryers, distillation, photovoltaics and system analyses were delivered. All presentations were video-taped. Visits to field installations were carried out.

The solar workshop carefully reviewed the recommendations made during the previous workshops and the group recommended that priority be given to:

1. Research, development and demonstration projects in solar, biomass, wind, and other appropriate energy systems.
2. Expand Education, and training in appropriate energy technology and uses through the UNICA network. Increase university and research institute interest.
3. Data are often insufficient in the Caribbean to permit the level of planning desired. Develop a data collection and analysis capability drawing on existing regional expertise.
4. Expand internal UNICA communications through newsletter, workshops, etc.
5. Analyze experience and develop an expanded appropriate energy network.
6. Develop and maintain the practice of collaboration research and exchange of data among UNICA members.
7. Seek external funding to finance increased energy technology development and transfer in the region.

#### D. Conclusion

The Caribbean region is richly endowed with renewable alternative energy sources which could in time provide energy self-sufficiency to the region. Three of the main sources--wind, biomass and solar --have been studied and analyzed. It is shown that these three provide the

most promising beginning to resource utilization and petroleum substitution.

Caribbean universities and research institutes could and should help in the development and utilization of these energy sources. The three UNICA sponsored workshops provide a mechanism to transfer technological and scientific knowledge within the Caribbean, one which will develop indigenous capabilities. Clearly these efforts must be expanded and institutionalized to further alternative energy development in the region.

This paper points out some of the impediments to cooperation as well as delineating a system of cooperation. One is insufficient data. Another is the inchoate but network among universities and research institutes in the Caribbean. This paper describes an effort for a more realistic plan for education, training, research and development and for deeper data collection and evaluation.

This is a pioneering effort occurring at a historical moment when there is a renewed interest in the "rediscovery" of the Caribbean region. This paper should be useful to all funding and development agencies which are becoming aware of the region and willing to do something helpful based on solid ground. This effort is a very healthy seed. Let us hope that somebody will water and nurture it for the benefit of the Caribbean community.



