CEER-X-147

DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE AND ENGINEERING IN THE CARIBBEAN

(Grant No. INT-8025593)

FINAL REPORT

Submitted to

NATIONAL SCIENCE FOUNDATION

By

Dr. Juan A. Bonnet, Jr.
Principal Investigator and Chairman
UNICA Science and Technology Commission

September 30, 1982

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

CEER-X-147

DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE AND ENGINEERING IN THE CARIBBEAN

(Grant No. INT-8025593)

FINAL REPORT

Submitted to

NATIONAL SCIENCE FOUNDATION

By

Dr. Juan A. Bonnet, Jr.
Principal Investigator and Chairman
UNICA Science and Technology Commission

September 30, 1982

TABLE OF CONTENTS

DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE AND ENGINEERING IN THE CARIBBEAN

EXECUTIVE SUMMARY

Today, as in the past, the Caribbean area remains of critical strategic importance to the United States and the rest of this Hemisphere. The region's geographic vulnerability is accentuated by its dependence on imported petroleum and petroleum products to satisfy the energy needs of industry, commerce, households and other vital activities of the society. Thus, the communities of the Caribbean Basin have been greatly impacted by the increases in the price of imported fossil fuels.

On the other hand, the region is blessed year-long with large amounts of natural energies including solar, wind, ocean, biomass and in some areas geothermal. It was the purpose of this project to develop the scientific and engineering capabilities of the universities and research institutes of the Caribbean region. The project used a unique institutional resource, the Association of Caribbean Universities and Research Institutes (UNICA) to foster a cooperative research effort aimed at increasing the capabilities of Caribbean institutions to assist in the introduction of alternative energy solutions into the region.

The research workshop format has been used and a network of scientists and engineers working in energy was established to promote cooperation, interchange of technical information and development of joint projects. Two workshops were carried out on the most promising energy alternatives the first was on wind energy in Barbados on December 6-9, 1981; the second on tropical biomass, held in Puerto Rico on April 28-29, 1982. In each of the workshops a list of needs and priorities in education and training, research and development, and demonstration projects was worked out as is reported in Appendices D and E. Proceedings of both workshops are in preparation for publication.

In addition to the presentation of workshops, efforts to collect basic energy data on Caribbean Basin countries in order to perform system analysis of appropriate energy alternatives were started and reported.

The project went beyond the scope originally contemplated. It has stimulated technological interchange between educators and scientists in the region who were unknown to one another before. It received support from the Caribbean Development Bank which sponsored the participation of government technical planners in the workshop. In addition, a two-week training section on solar energy was sponsored by the Venezuelan government. Other activities generated by the project are discussed elsewhere in this report.

A third workshop--on solar energy--is being planned for early 1983 and a proposal being prepared to solicit funds to carry it out.

The project was conceived by the Science and Technology Commission of UNICA and the workshops were organized under the leadership of the Center for Energy and Environment Research (CEER) of the University of Puerto Rico, in cooperation with the University of Miami and the University of the West Indies. The UNICA staff also collaborated at all times with the organizers.

The ensuing substantive report and appendices summarize the major activities and accomplishments of the project.

PROJECT REPORT

General

The project to Develop Alternative Energy Science and Engineering in the Caribbean represents the first indispensable step toward a major coordinated program of technology transfer and adaptation to be undertaken as a cooperative effort by the universities and research institutes

of the region. Funding by the National Science Foundation allowed the planning, organizing, carrying out and reporting of two workshops--one on wind and the other on biomass--covering various aspects of the alternative energy problem. The Exxon Educational Foundation, through the UNICA Foundation, also contributed in this part of the project.

Later phases of the project involve the completion of research plans and proposals resulting from the workshops and data gathering in the region, the preparation of education and manpower training plans, and the compilation of reports on the alternative energy data base and organization established. A proposal to fund the next phase, which includes a solar energy workshop in 1983, is being prepared.

Publications

The project has produced two technical papers:

(1) "The Energy Alternatives for the Caribbean" by J.A. Bonnet, Jr., presented at a Workshop on Wind as an Energy Alternative for the Caribbean, Bridgetown, Barbados, December 7, 1981;

(2) "Alternative Energy in the Caribbean" by H.P. Harrenstien, presented at the First Pan American Congress on Energy, San Juan, Puerto Rico, August 3, 1982.

Dr. Bonnet is the Chairman of the Science and Technology Commission of UNICA and Principal Investigator of this project and Dr. Harrenstien is the Co-principal Investigator.

The first paper, a copy of which is included as Appendix A to this report, discusses the energy situation in the Caribbean and outlines efforts underway to develop renewable energy alternatives in the region. This work is based on the author's experience in the region and on information received from UNICA contact persons.

The second paper, attached as Appendix B, gives further details about the planning and implementation of the project.

Project Application Potential

This project focused its efforts on the island communities of the Caribbean Basin. The islands have over eighteen (18) million inhabitants in 42,213 square miles. It is estimated that 37,950,000 Bbls. of oil per year are imported by these islands. Table I summarizes geographic, demographic and other data on the Caribbean region.

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

Harrenstien (Appendix B) computed the value of contribution in Bbls. of oil saved per year for each alternative energy technology at the end of full commercialization by the year 2000. This is presented in Table II, 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 become energy self-

sufficient, as far as electrical generation is concerned. A plan of action and preparedness to move toward that goal are needed.

From Table III we can observe that wind and biomass (bagasse) show significant promise for making major contributions in the immediate future. Recognizing this condition the UNICA Commission on Science and Technology selected these two energy sources for the first two workshops. 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 focus to initiate educational and research activities in their institutions. Appendix C includes the names and addresses of UNICA Commission on Science and Technology and contact persons.

A questionnaire was circulated to all UNICA contact persons and two follow up notices sent to assure maximum response. Only five of the 15 contact persons answered the questionnaire. The others claimed the information about their islands was not readily available to them. This first 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. Table III summarizes the energy projects in the Caribbean region. Wind and biomass projects encompass the major efforts being pursued, which confirms our previous observation of the importance of these two renewable energy sources for the region.

The paper by Dr. Bonnet (Appendix A) was presented at the Wind Workshop in Barbados to the UNICA contact persons, who were requested to review it carefully and give their comments and suggestions. Only the representatives from Guyana, the Netherlands Antilles and the

Caribbean Development Bank submitted comments; these were incorporated in the final version of the paper. The other contact persons merely stated that the paper reflected the current state of affairs in their islands.

The papers by Bonnet (Appendix A) and Harrenstien (Appendix B) present the most up to date general description of renewable alternative energy projects and potential in the Caribbean region and in this sense constitute major contributions of this project.

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 workshop program is included in Appendix D.

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 covering 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 which is enclosed in Appendix D.

It is interesting to notice that the recommendations have similarities 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 capabi-

lities, 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 feels 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.

Appendix D includes the evaluation of the workshop made by the participants.

2. Workshop on 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. The program of this workshop is enclosed in Appendix E. 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. The reports of the group sessions are enclosed in Appendix F.

The evaluation of this workshop indicated that it was even more successful than the previous one. From the experience and recommendations made after the first (wind) workshop, changes in organization and strategies were made. The evaluation is enclosed in Appendix F.

CONCLUSION

It is clear that the Caribbean region is richly endowed with renewable alternative energy sources which could provide energy self-sufficiency to the region in the decades ahead. Two of the main sources--wind and biomass--have been studied and analyzed. Caribbean universities and research institutes should help in the development and utilization of these two energy sources. This is a pioneering effort occurring at a historical moment when there is a renewed interest in the "rediscovery" of the Caribbean region. This report 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.

It is also clear to the authors of this report and to the participants that at this stage a much more detailed resources assessment is needed before a realistic plan for education and training and research and development can be formulated. In this respect the activities and accomplishments of this project represent important steps in the right direction.

TABLE 1. CARIBBEAN DEMOGRAPHIC DATA

Island	Language	Latitude	Longitude	Area (sq.mi.)	Population	Population Density	Highest Point (ft)	Length (mi.)	Width (mi.)	Wind Exposure (mi.)	Electrical Consumption in 1980 kwh/person	BBls/yr for Electricity Production
Trinidad	E	10.5	61.5	1864	1,090,086	585	3085	50	30	50	1442	3.225
Tobago	E	11.0	60.5	116	46,914	404	1860	25	6	6	500 (est)	0.046
Grenada	E	12.0	62.0	120	94,000	783	2756	16	8	12	264	0.055
Grenadines	E	13.5	62.0	35	12,000	343						
St. Vincent	E	13.0	61.5	133	106,000	797	4048	20	12	17	189	0.039
St. Lucia	E	14.0	61.0	233	120,000	515	3145	26	13	20	417	0.098
Barbados	E	13.0	59.5	166	250,000	1506	1104	26	15	18	1164	0.523
Martinique	Fr	14.5	61.5	425	369,000	868	4700	38	15	38	526	0.382
Dominica	E	15.5	62.0	305	27,000	252	4672	30	12	30	208	0.031
Marie Galante	Fr	16.0	62.0	105	26,000	248		8	8	8	500 (est)	0.026
Guadeloupe	Fr	16.0	62.0	583	317,000	544	4870	30	25	30	800 (est)	0.499
Montserrat	E	17.0	62.5	39	12,700	326	3002	10	5	8	787	0.020
Antigua	E	17.0	62.0	108	69,700	645	1319	12	10	12	716	0.104
Barbuda	E	17.5	62.0	62	1,200	19						
Nevis	E	17.5	62.5	36	15,000	417	3232	8	7	8	500 (est)	0.015
St. Kitts	E	17.5	62.5	64	35,000	550	3792	22	6	22		0.053
Saba	Du	17.5	63.0	5	1,200	240	3000				500 (est)	0.001
St. Maarten	Fr/Du	18.0	63.0	14	7,000	500		10	6	6	500 (est)	0.007
Anguilla	E	18.0	63.0	35	5,000	140	200	17	3	3	500 (est)	0.005
Tortola	E	18.5	64.5	24	9,000	375		8	3	4	500 (est)	0.009
St. Croix	E	17.5	65.0	84	63,000	470	1200	25	6	10	500 (est)	--
St. John	E	18.0	64.5	20			1300	8	3	5		0.062
St. Thomas	E	18.0	65.0	28			1700	12	4	8		--
Puerto Rico	Sp	18.5	66.5	3435	3,176,000	925	4388	110	35	90	3502	21.871
Dominican R.	Sp	18.5	72.5	18,811	5,128,000	273	9000	230	100	230	539	5.434
Haiti	Fr	18.5	72.5	10,714	4,800,000	448	10,200	100	100	100	58	0.836
Jamaica	E	18.0	77.5	4400	2,100,000	477	7402	140	40	100	1014	4.189
Aruba	Du	12.5	70.0	69	61,000	884				--	1000 (est)	0.120
Curaçao	Du	12.5	69.0	180	146,000	811				--	1000 (est)	0.287
TOTALS				42,213	18,137,800					827		37.950

TABLE II

CARIBBEAN ISLANDS ALTERNATIVE ENERGY CONTRIBUTIONS

Alternative Energy Technology	Estimated Potential Savings in BBLS/yr by year 2000	Number of* persons	Number of* sq. miles	Number of* miles exposure	Potential Savings * Millions BBLS oil/yr by year 2000
1. Solar Hot Water	0.692 BBLS/person/yr	14,961,800			10.354
2. Co-generation	1.178 BBLS/person/yr	14,961,800			17.625
3. Hydroelectric	535.7 BBLS/sq.mi/yr		38,778		20.772
4. Solid Waste	0.217 BBLS/person/yr	14,961,800			3.247
5. Small Wind Machines	0.091 BBLS/person/yr	14,961,800			1.366
6. Large Wind Machines	30,667 BBLS/mi/yr			737	22.601
7. Bagasse	1,755 BBLS/sq.mi/yr		38,778		68.055
8. Solar Ponds	151.4 BBLS/sq.mi/yr		38,778		5.871
9. Photovoltaic	0.290 BBLS/person/yr	14,961,800			4.339
10. Ocean Thermal (OTEC)					?
11. Geothermal					?
12. Other					?
TOTAL					154.230

*Puerto Rico excluded. (See Scott-Harrenstien paper for Puerto Rico estimates.)

TABLE III

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Antigua	1. Renewable Energy-Wind	Wind Generators (50-100 KW)	UN Interim Fund
	2. Renewable Energy-Wind	Wind Generators (12KW)	Rockefeller Fund
	3. Renewable Energy-Solar	Photovoltaic pumping System	CDB
Bahamas	1. Oil	Exploration	UNDP/IBRD
Barbados	1. Renewable Energy-Biomass	Bagasse Burning Studies	CIDA/CDB
	2. Renewable Energy-Wind	Pilot Generator (200 KW)	IDB
	3. Renewable Energy-Biogas	Biogas Digestors	CDB
	4. Renewable Energy-Solar	Solar Air Conditioning	USAID/CDB
	5. Renewable Energy-Solar	Solar Collector Manufacturing	USAID/CDB
Curacao	1. Renewable Energy-Wind	Wind Turbine for Cooling	Univ. of Neth. Antilles
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	Brasil
	7. Renewable-Wind	Wind Turbine	OLADE
	8. Renewable Energy-Geothermal	Investigations	OLADE
Grenada	1. Hydro	Hydrological Resource Assessment	Venezuela
	2. Hydro	Micro-Hydro Identification	OLADE
	3. Renewable Energy-Biogas	Biogas Unit Comparison	OLADE

TABLE III (CONT.)

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Guyana	1. Renewable Energy-Biomass	Technical Assistance, Ethanol Production	Brasil
	2. Renewable Energy-Biomass	Utilization of Rice Husks	USAID
	3. Renewable Energy-Biomass	Gasification of Wood Waste; Oil-to-Charcoal conversion of alumina and bauxite 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

TABLE III (CONT.)

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Mexico	1. Renewable Energy-Solar	Water Pumping	West Germany and France
	2. Renewable Energy-Solar	Rural Electrification	CONACYT
	3. Renewable Energy-Solar	Solar Research and development projects	France - CONACYT
	4. Coal	Exploration	Canada and Israel-CONACYT
	5. Renewable-Hydro	Investigations	National Energy Commission (Comisión Nacional de Energía
	6. Renewable-Geothermal	Development	National Energy Commission
			National Energy Commission
Montserrat	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	Goddard Space Laboratory-NASA
	5. Renewable Energy-Biomass	Biomass from Sugar Cane and Tropical Grasses	DOE
St. Kitts-Nevis	1. Electricity	Generation and Transmission Development	CDB

TABLE III (CONT.)

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
St. Lucia	1. Electricity Generation	Generation Expansion	CDB
	2. Renewable Energy-Wind	Wind Power System	CDB
	3. Renewable Energy-Wind	Wind Power Chilling	Privately
	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 Arrowroot	CDB
	3. Renewable Energy-Wind	Wind Power System	CDB
	4. Renewable Energy-Biogas	Biogas Plant	EDF
Trinidad & Tobago	1. Renewable Energy-Solar	Air Conditioning	----
Venezuela	1. Renewable Energy-Wind	Photovoltaic Project	Ministry of Energy and Mines

SOURCE: Int'l. Bank for Reconstruction & Development (June 1981) and information supplied by UNICA contact persons.

LIST OF APPENDICES

APPENDIX A

Bonnet, Juan A., Jr., 1981: "Energy Alternatives for the Caribbean," presented at the Workshop on Wind as an Energy Alternative for the Caribbean, Bridgetown, Barbados, December 7, 1981.

APPENDIX B

Harrenstien, H.P., 1982: "Alternative Energy in the Caribbean," presented at the First Pan American Congress on Energy (UPADI-82), San Juan, Puerto Rico, August 3, 1982.

APPENDIX C

1. Members of UNICA Commission on Science and Technology
2. UNICA contact persons

APPENDIX D: Wind Workshop

1. Summary Report
2. Education and Training Needs: Workshop Group No. 1 Report prepared by Dr. Howard P. Harrenstien, Moderator
3. Research and Development Needs: Workshop Group No. 2 Report prepared by Dr. Edwin Nuñez, Moderator
4. Demonstration Needs: Workshop Group No. 3 - Report prepared by Dr. Modesto Iriarte, Moderator
5. Evaluation
6. Workshop program

APPENDIX E: Biomass Workshop

1. Summary Report
2. Education and Training Needs: Workshop Group No. 1 Report prepared by Dr. R.L. Sullivan, Moderator
3. Research and Development Needs: Workshop Group No. 2 Report prepared by Dr. Al Binger, Moderator
4. Demonstration Needs: Workshop Group No. 3 - Report prepared by Dr. Modesto Iriarte and Mr. Salvador Lugo, Moderators
5. Evaluation
6. Workshop program

ENERGY ALTERNATIVES FOR THE CARIBBEAN

By

Dr. Juan A. Bonnet, Jr.

ABSTRACT

Since all of the Caribbean countries except Trinidad and Tobago are petroleum importers, they have all been hurt by the dramatic increases in the price of petroleum during the last decade. Crude oil production has increased significantly in Latin America during the last three years, and the governments of Mexico and Venezuela are attempting to control oil sales in the Caribbean by offering incentives for energy conservation and the development of alternative sources. International agencies such as the World Bank and the United States Agency for International Development are now working with the Caribbean Development Bank and CARICOM to develop alternative energy sources.

Many different energy sources can be developed in the Region. Solar energy has received the most attention, but its use is still limited to crop drying, water purification, heating and distillation. Hydropower is used extensively in Dominica, Haiti and the Dominican Republic, and has great potential in others. The use of sugarcane and other fast-growing plants makes biomass a significant alternative. An experimental farm using the bioconversion of organic wastes is being operated successfully in Puerto Rico. Geothermal power and ocean thermal energy conversion (OTEC) are two potential energy sources that are basic to Caribbean geography.

Historically speaking, wind is one of the oldest sources of energy in the Caribbean, and preliminary studies have shown that several Caribbean islands could benefit greatly from this alternative. However, four environmental factors (noise, radio, interference, air disturbance and unsightliness) have to be addressed before wind energy becomes more widely accepted. Finally, in view of the perilous dependence on petroleum, conservation is per se also a potential energy transfer source.

ENERGY ALTERNATIVES FOR THE CARIBBEAN
By Dr. Juan A. Bonnet, Jr.

INTRODUCTION

There was some good news for the developing countries from Geneva at the end of November 1981. The Organization of Petroleum Exporting Countries (OPEC) agreed to increase world oil prices to US$34 a barrel, but it also decided to freeze this basic price until December 1982, thus protecting poorer countries from unexpected and unmanageable price increases.[1]

Yet, unless long range steps are taken soon, the OPEC action may not be enough.[2] Nearly 100 developing countries depend on oil to meet more than 60 percent of their energy needs. Most of them import four-fifths of their total oil requirements. The price of oil, in inflation-adjusted terms, has quintupled over the past decade , and many analysts predict price increases of three percent annually. This means that the poor countries now spending $50 billion a year for imported oil could be paying $110 billion a year by 1990.

To offset this economic drain, many countries are turning to the most readily available alternative supply. Forty percent of the developing world's timber reserves may literally go up in smoke as households and small industry substitute firewood for oil. In a number of Caribbean countries exploitation of wood resources is not in equilibrium with regeneration rates. Wood and charcoal meet a large part of Haiti's energy requirements and, in a lesser degree, those of countries with forest reserves such as Belize, Dominican Republic, Grenada, Guyana and St. Lucia.

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

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

During 1981 there has been an increase of discussion about energy.[2] In November 1981 south and north talked about energy at the Cancún, Mexico Summit Meeting. Before this in August there were discussions about renewable energy at the United Nations Conference on New and Renewable Sources of Energy in Nairobi.[3] For months there have been discussions about a World Bank proposal to set up a separate energy affiliate within the Bank, but up to now no concrete agreements have been reached.

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

nearly 10 percent and the region's share of the world oil markedly rose from 7.7 percent in 1977 to 9.8 percent in 1980. At year end, the total oil output of the region reached 2.123 billion barrels (337,530,027m^3), exceeding consumption by about 700 million barrels (111,291,106m^3), an increase of 100 million barrels (15,898,729m^3) over 1979. The rate of growth in production was the highest since 1973, and compares favorably with the 8.5 percent expansion of 1979. Combined production of Mexico and Venezuela accounted for nearly 75 percent of the region's crude oil production from 1975 to 1980. Although Venezuela's share fell from 53 percent in 1975 to 37 percent in 1980, Mexico's production rose from 18 percent of the region's output to 37 percent during the same period. Concerning oil exportation, "the single most important event during the past five years has been Mexico's contribution to the region's increased sales of crude to external markets," the IADB report said. Mexican oil exports increased 114 percent in 1977, 79 percent in 1978, 47 percent in 1979 and 55 percent in 1980 when they totaled about 303 million barrels. Production also expanded in Argentina, Brazil, Chile, Peru and Guatemala, but it declined in Bolivia, and Trinidad and Tobago. In Venezuela, production declined by almost 8 percent as a result of conservation measures enforced by the Government.[4]

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

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

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

evaluate experiences in different countries with the adoption of the technologies, and make global assessments of future technological developments and their implications for developing countries.

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

1. Regional Basic Support

   a. energy planning
   b. information and dissemination
   c. training

2. Integral Regional Development

   a. hydroelectric
   b. firewood and charcoal
   c. liquid fuel production
   d. solar energy
   e. vegetable residues
   f. geothermal energy
   g. biogas
   h. wind power

THE CARIBBEAN REGION

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

The Caribbean nations share several energy characteristics:[7]

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

2) there are no organized markets for 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 amount of imported petroleum is used by the electric utility companies which have peak capacities that range from less than ten megawatts to several hundred megawatts (See Table 1 and Figures 1A

and 18). 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 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 consultant for the United Nations Development Programme (UNDP) concluded recently that hydro, geothermal, solar and charcoal alternatives should be developed with priority in the Caribbean. This recommendation generally agrees with the report Energy Resources in the CDCC member countries.[8]

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

1) Assessment of major sources of non-conventional energy and their potentials for utilization.

2) Management will involve:

   a) Cooperation and technical assistance in the application of energy accounting systems which may be used as the basis for the formulation and implementation of sound national energy policies and programmes.

   b) Reinforcement of regional and subregional integrated non-conventional energy activities with the objective of a fuller exchange and dissemination of all available information and provision of training opportunities.

   c) Development of a cooperative programme for the implementation of appropriate technologies and practices for waste disposal with special attention to recycling, energy generation and the special problems of the smaller islands.

The sources that are 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.[10] 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.

Notwithstanding these positive situs of interest and action on aspects of the Caribbean energy question, it may be observed that President Ronald Reagan's Caribbean Basin Initiative proposal did not made significant mention of energy, even though Puerto Rico has proposed that the Center for Energy and Environment Research of the University of Puerto Rico become the Research and Development center on energy in the Caribbean. CEER's twenty five year background of dealing with energy - the last five specifically on alternative and renewable energies - are a valuable platform from which many problems may be identified and solved. An encouraging sign may be recent indications of awareness that the CBI will make impact upon existing energy use patterns witnin the Caribbean. This may lead to increasing awareness of the need to confront the energy question, non-renewable but more importantly renewable, in the Caribbean more comprehensively.

Geothermal Power

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

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

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

Solar Energy

Solar Energy as an alternative source of energy has received the greatest attention in recent times. Essentially all our energy, except nuclear and geothermal, is derived directly or indirectly from the sun. The solar radiation in the Caribbean Region is of the order of two thousand kilowatt hours per square meter per year. Average air temperature varies from about 78°F in February to 83°F in September. Nearly fifteen times more solar radiation reaches the earth's surfaces than the total consumption of commercial energy. Presently, solar energy is used on a very limited scale in the Caribbean for crop drying, water purification, heating and distillation. Two solar stills have been built by a foreign research institutes, one in Haiti and one on St. Vincent in the eastern Caribbean. These stills have been successfully providing potable water to small rural communities. Solar crop-dryers have been built 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. The development of solar industrial steam generators and solar air conditioner units is also being pursued by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico. 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, 3860sq.ft. of solar collectors were installed, with a 2500 gallon hot water tank to supply the needs of more than 1000 residents of the building.

In 1981 a detailed design for a solar energy system to provide 210°F hot water to the Nestlé-Libby food processing plant at Santa Isabel, P.R. was completed. The final design consisted of a field of sunmaster tube collectors with an active area of 50,400sq.ft. Detailed system simulation studies predicted the solar array would provide 10^{10} BTU/year to three different processes including pasteurization, sanitation and boiler preheat, thus representing an annual saving of approximately 102,000 gallons of #6 fuel oil.

Also in Puerto Rico a 240sq.ft. shallow solar pond system is currently being designed for hot water generation and storage for a 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, utility boat technology, have been built, given promise of great durability. In the Dominican Republic and on the Caribbean island of Arguilla 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 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 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.

It is my very personal belief that if industrial solar energy is not economically viable in the Caribbean, it probably will not be viable anywhere else in the world.

Ocean Thermal Energy Conversion (OTEC)

As a potential source for commercial supplies of electrical energy, ocean thermal energy conversion (OTEC) offers a 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.[19]

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 has been actively working on the development of an OTEC Project on the southeast coast of Puerto Rico. Its floating platform laboratory has run longer, continuously, than any other similar data-

gathering station in the world at probably the best site for this purpose in the United States.[11] Jamaica is planning an OTEC demonstration project in conjunction with the governments of Sweden, Norway and Finland through a consortium established for the purpose.[12] 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 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 3000 megawatts exists. Belize is interested in mini hydro projects. A Colombia engineering firm is providing technical assistance to Haiti and Dominica in order to develop small-scale hydroelectric resources.[10] El Centro la Gaviota in Colombia has 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, Trinidad and Tobago. Sugar factories in Haiti are able to satisfy all their energy requirements from bagasse and in Barbados 90 percent of their energy requirements. Considerable use is made of bagasse as fuel for sugarmills in Guyana, Puerto Rico, Jamaica and other countries. Firewood, charcoal and bagasse provide an estimated 80 percent of all primary energy supplies in Haiti.

The energy content of dry bagasse is about 5.15 kilowatt hour per kilogram. An extensive program of more than $1.60 million for the development of bagasse and tropical grasses for energy use has 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 manufacturing 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 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'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 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 that are 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.

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 it can be used for cooking, heating and refrigeration. Once the gas production has ceased in the digester, the residue forms an excellent fertilizer which can be used to grow algae and the liquid can be extracted for irrigation.

A 1,200 pig farm is being operated successfully by private enterprise in the south of Puerto Rico. All of the electricity at the farm comes from local biogas production, and also algae is grown as a feed supplement for the pigs. It has been estimated than the manure from one large dairy cow could yield 2.5 cubic meters of biogas per day, roughly equivalent to one-third of a gallon of gasoline. It has been estimated that waste from one thousand poultry broilers will be capable of producing about 10 cubic meters of methane per day, energy equivalent to one hundred kilowatt hours per day. If one assumes 30 million 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 400 registered Holsteins, to be increased to 500 head during 1982. The farm's 1982 average power demand will be about 1,680KwH/day, and 24.6 tons of raw manure will be 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 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 10 miles per hour. Because of this favorable condition, a 200 kilowatt wind power generator was installed by the U.S. Department of Energy (DOE) on the island of Culebra in Puerto Rico. This energy machine 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 a long time. Prior to the introduction of machinery for crushing sugarcane, small factories were situated on elevated land in order to use the available wind for driving windmills to crush the cane. This is true for Jamaica, Antigua, Puerto Rico and Barbados. In Antigua the Rockfeller Foundation has financed a 12 kilowatt windmill generator. Also a proposal for two pilot wind generators (50 to 100 kilowatt) has been sent to the United Nations Interim Fund. The Barbados-based Caribbean Meteorological Institute is an active participant in collating information about wind speeds in the Caribbean Region. A wind turbine generator factory has been installed in Puerto Rico by the Future Energy R&D Corporation.

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

1) Noise effect. The noise produced by large wind turbine generators is the most objectionable environmental effect. About 1 percent of the time a sound amplification or focusing problem raises the noise level to values of up to 77 decibels. This is equivalent to twice the noise level experienced at a busy metropolitan intersection.[12] Reducing rotor speed apparently solves the problem. Efforts must therefore be made to define standards of acceptable noise levels for these environments and then to develop adequate computer programs to predict the noise level of planned wind turbine generators.

2) Radiointerference effects. The rotation of wind turbine blades generate radio frequency noise which may interfere with TV reception.[13] There are various solutions to this problem depending upon the local situation.

3) Air disturbance and reduction of wind power in nearby private properties. Wind flow pattern is altered by the presence of a wind turbine machine. At optimum operating condition of the turbine the effect might be felt as far as 15 diameters of the machine rotor, causing a "wind shadow" an uneven flow of air to the blades. For a 300ft. diameter rotor machine the effect would be felt for a distance of 4500ft which could affect the neighbor's wind turbine.

4) Aesthetic effects. Wind turbines can present an objectionable sight when located nearby sophisticated residential areas[13].

All environmental impacts of wind turbine appear to be insignificant when compared with other energy sources. Consequently, more than 100 United States electric utilities are considering wind projects.[13] Southern California Edison is already testing wind machines in the San Gorgonio Pass and has signed agreements to purchase as much as 85 megawatts from 50 wind turbines. Hawaii has signed a contract with Wind Farms, Inc. to install 20 megawatt wind turbines on Oahu by 1985. Wind Farms, Inc. has persuaded Pacific Gas & Electric Co. to buy as much as 350 megawatts of wind power.[14] Also three 2.5 megawatt wind turbines (MOD-2) are operating at Goodnoe Hills, Washington for the Bonneville Power Administration[15] with turbine blades 300 feet long towers 200 feet tall; and the blades rotating at 17.5rpm. In Germany MAN is engineering and constructing a Growian (grosse wind energian lage) 3 megawatt wind energy machine.[16]

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

CONCLUSIONS

This paper briefly discussed the renewable energy technologies, geothermal, solar, OTEC, hydro, biomass, bioconversion and wind which have the largest potential for the Caribbean Region. But let 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 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.[17]

Caribbean renewable energies development and potentials are summarized in Table 2. It is important that these renewable energies be examined in the light of four basic forms of energy use, namely: liquid transport fuels, centralized electric power, decentralized power, and heat. These are outlined in Table 3, "New and Renewable Energies Technologies and Applications", prepared for the United Nations Conference on New and Renewable Sources of Energy. Among new and renewable energy technologies, minihydro, small-scale solar and biomethanation are already feasible and available for rapid proliferation in a decentralized mode. They can all be used in the Caribbean Region. Table 4 summarizes present demonstration projects in renewable energies in the Caribbean Region. More details of some of these projects are given in Energy Resources in the CDCC member countries report.[18] 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. Because of their great near term potential Table 5 list selected Biomass Energy Systems for Caribbean countries. 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.

Other new and renewable energy technologies such as the ocean thermal energy conversion, geothermal energy, large-scale solar ponds, tar sands and oil shales are all very promising. With suitable support for research, development and demonstration, these resources could emerge as significant options within short to medium time frames.

Although this paper's concern is with alternate and renewable energies for the Caribbean, I cannot end without pointing out that there is also another source of energy - conservation. A recent study at CEER shows that in 1981 Puerto Rico transportation used up 52% of all energy created by petroleum on which it is nearly totally dependent and 83% of that was accounted for by private passenger vehicles, two-thirds in urban traffic. Much of this is waste, remediable by a relatively few "fixes" - engineering and administrative. Significantly, the report finds that in the area of transportation alternate fuels would create only a "fractional difference".[20] All the more reason for increasing efforts to create alternate and renewable energies for essential needs.

REFERENCES

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

17) Energy/Environment Management: A Broad Perspective for the Islands of the

Caribbean. Juan A. Bonnet, Jr. and Edward L. Towle. Background paper for Workshop II on Energy/Environment Projects for the Caribbean Area. Key Biscayne, Florida, March 19-20, 1981.

18) Solar Ocean Energy Liaison, January 1982.

19) Energía Oceano-térmica para el Caribe. Juan A. Bonnet, Jr., Manuel García Morín y Donald Sasscer. In press.

20) Transportation's Energy Conservation in Puerto Rico: Potentials Approach Methodology and Prospect to 1985. Jaro Mayda, CEER publication X-132. October 1981.

FIG. I-A I-B ELECTRICITY CAPACITY AND PRODUCTION PER CAPITA IN SOME ISLANDS AND COUNTRIES IN THE CARIBBEAN

Figure I-A

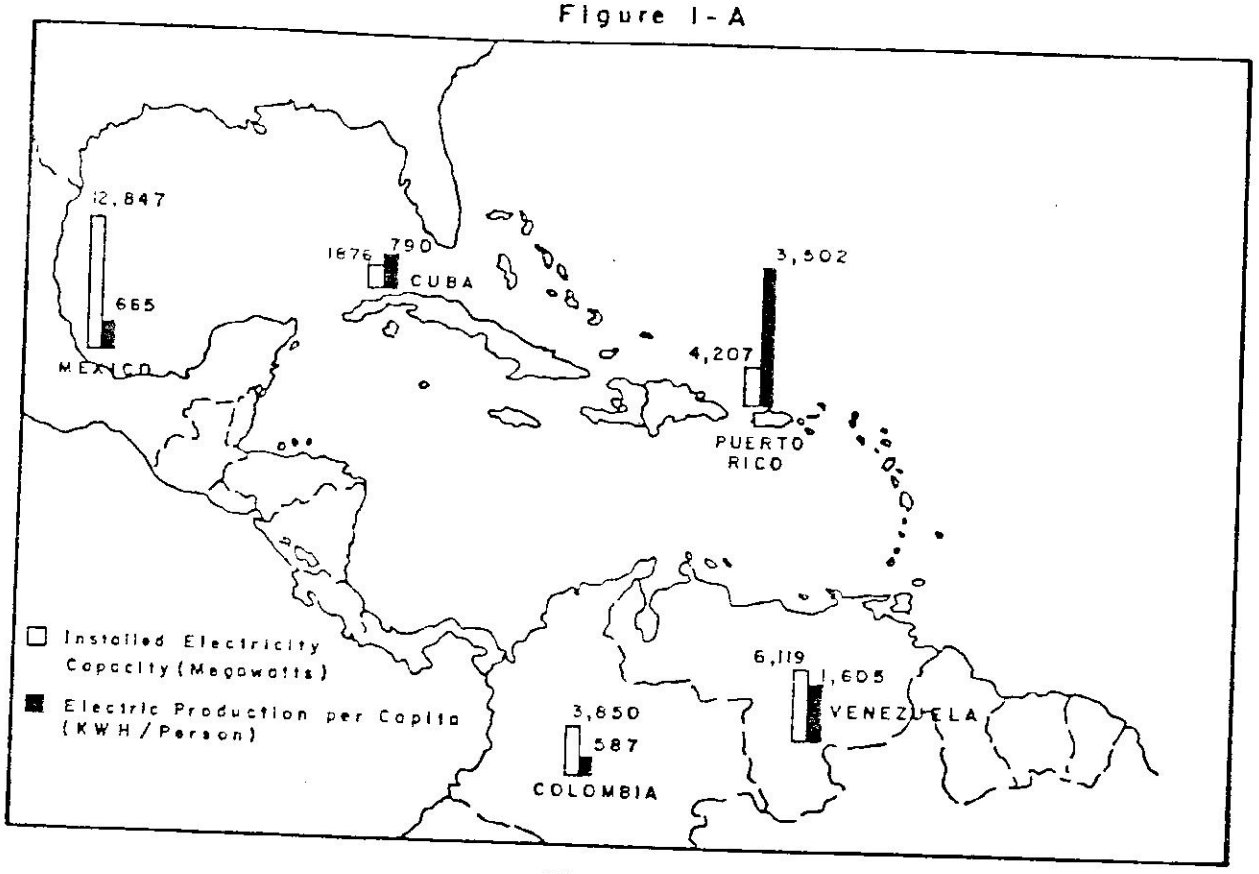

Figure I-B

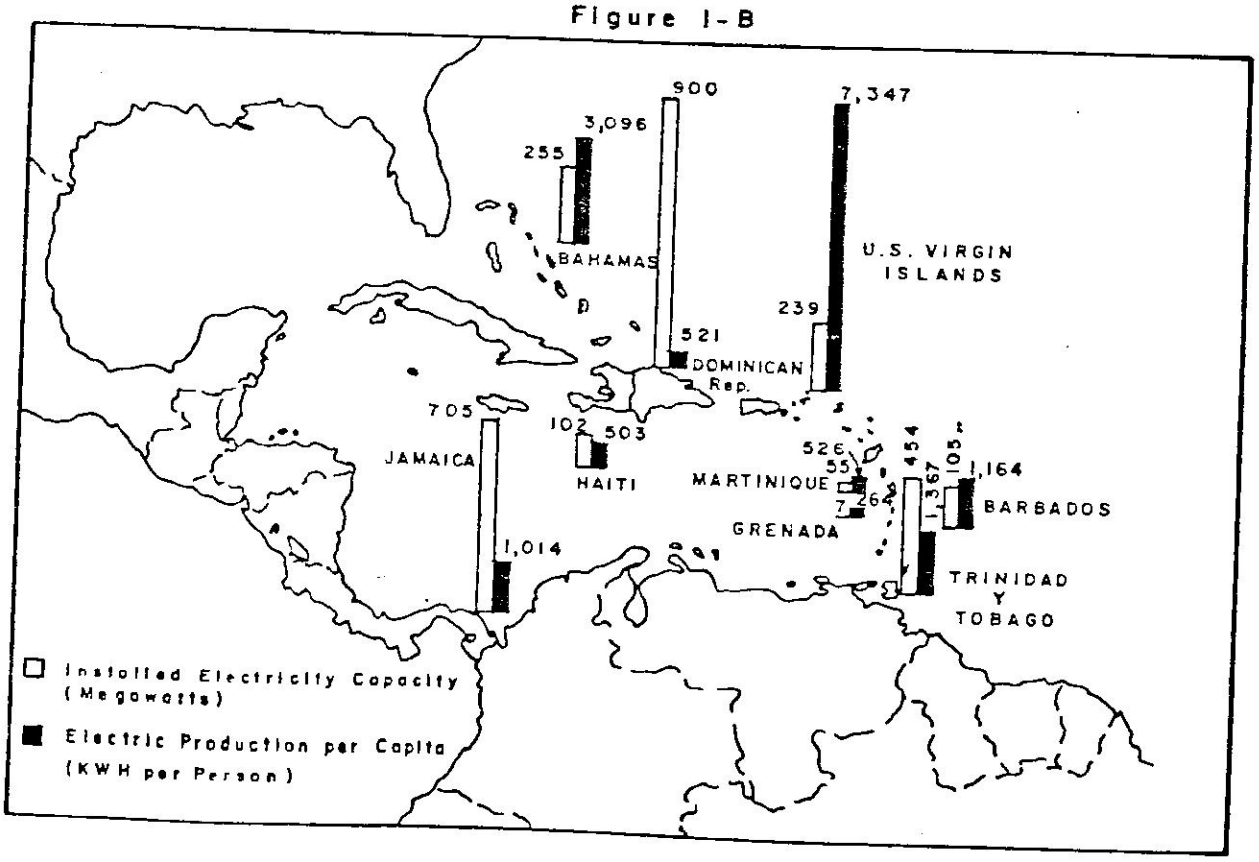

Figure 2

PLATE BOUNDARIES OF THE CARIBBEAN REGION

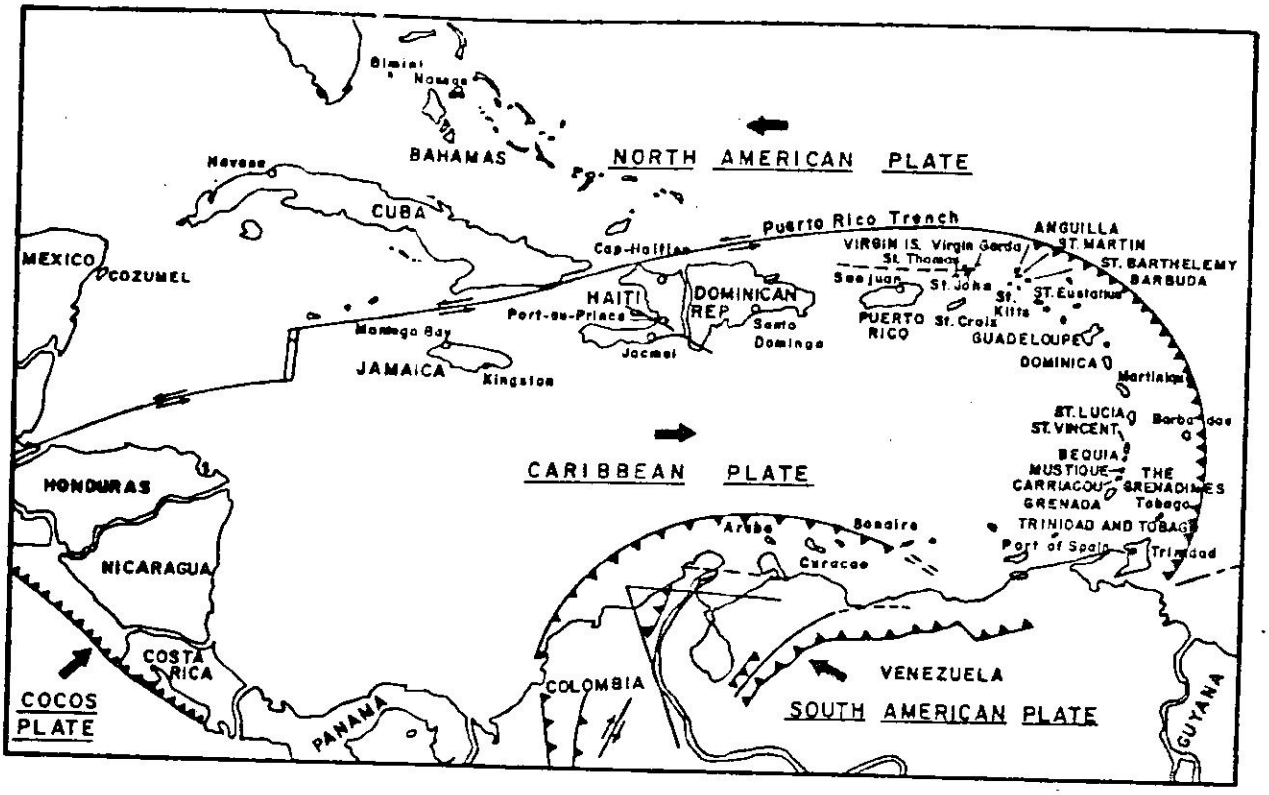

Figure 3

PLATE CONFIGURATION IN EASTERN CARIBBEAN

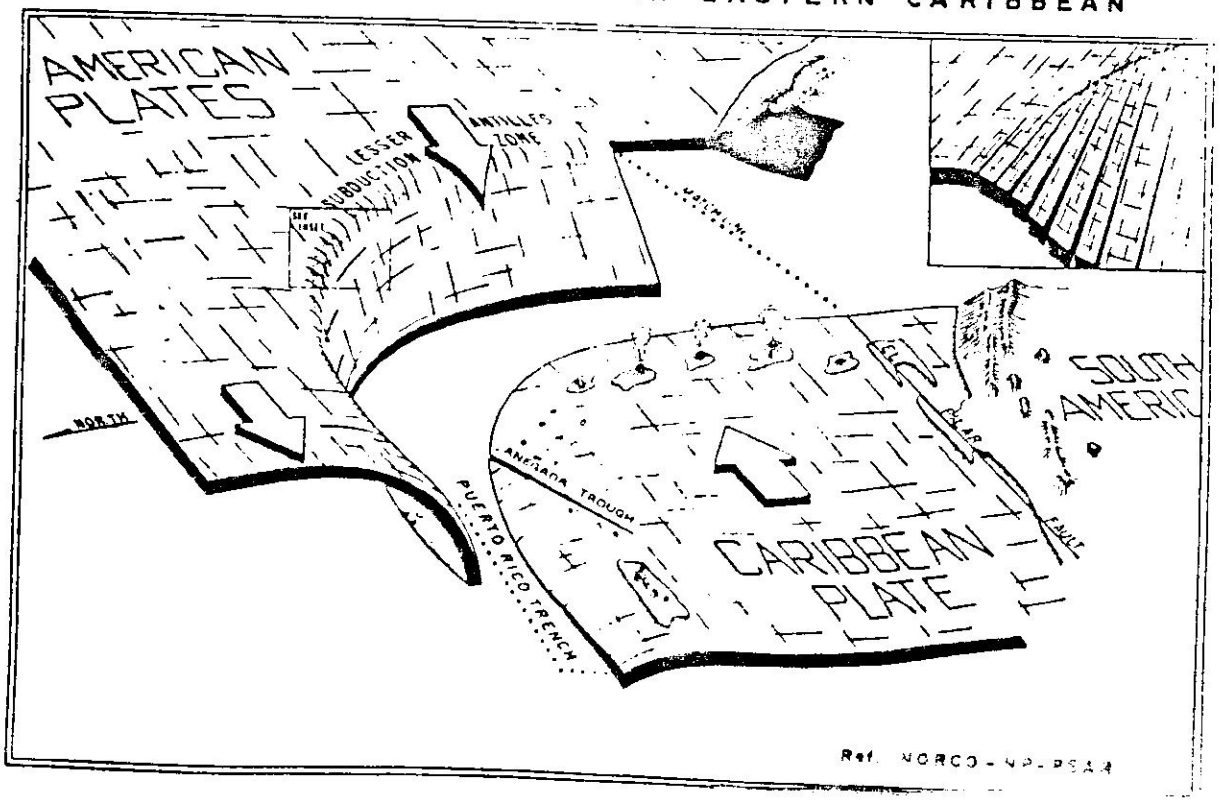

TABLE 1

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

Island or Country	A (1) Area (Km^2)	B (1) Population (thousands)	C (2) Installed Electricity Capacity (Megawatts)	D (2) Yearly Electricity Production (Millions of KwH)	E (3) Electric Production per capita (EPPC) (KwH/Person)	F (4) Gross National Product per capita (GNPPC) (US$/Person)	G (4) EPPC/GNPPC (KwH/US$)	H (5) Refinery Capacity (Thousands of M^3 / day)	
Antigua	435.2	76	26	53	716	950	0.75	2.861	(18)*
Bahamas	N.A	218	255	675	3,096	2,620	1.18	79.493	(500)*
Barbados	425	250	105	266	1,164	1,940	0.6	0.477	(3)*
Colombia	1,139	26,000	3,850	15,343	587	1,010	0.58	25.756	(162)*
Cuba	115,000	9,800	1,876	7,750	790	1,410	0.56	21.3	(134)*
Curacao-Aruba[a]	444	222	124	--	--	--	--	122.42	(770)*
Dominica	42.4	77	6	16	208	440	0.47	1.876	(11.8)*
Dominican Republic	49,000	5,300	900	2,763	521	990	0.53	5.246	(33)*
Grenada	307	106	7	28	264	530	0.5	N.A	(N.A)*
Guyana	83,000[a]	812	180	425	523	560	0.94	0	(0)*
Haiti	28,000	4,900	102	276	56.3	260	0.22	0	(0)*
Jamaica	11,000	2,100	705	2,130	1,014	1,150	0.88	5.246	(33)*
Martinique[a]	1,088	369	55	194[d]	526	2,900	0.18	1.637	(10.3)*
Mexico	1,972,947	70,000[a]	12,847[d]	46,612[d]	665	1,640	0.40	80.924[d]	(509)[d]*
Monserrat	100	12.7	4	10[c]	787	920	0.85	0	(0)*
Puerto Rico	8,960	3,176	4,207[b]	11,121[b]	3,502[b]	3,172[b]	1.10	45,947[f]	(289)[f]*
St. Kitts-Nevis	166	50	13	27	540	660	0.81	0	(0)*
St. Lucia	589	120	15	50	417	630	0.66	0	(0)*
St. Vicent	384	106	9	20	189	380	0.49	0	(0)*
Trinidad & Tobago	5,000	1,200	454	1,640	1,367	3,390	0.40	68,523	(431)*
Venezuela	912,000	14,500	6,119[e]	23,276[d]	1,605	3,120	0.51	231.009	(1,453)*
Virgin Islands(US)	94.4	136	239	720	7,347	3,603	2.0	100.797	(634)*

References: 1. World Development Bank, August 1980/Data 1978 and World Development Bank, August 1981/Data 1979
2. Energy Resources in the CDCC Member Countries, El CEPAL/CDCC/65 28 May 80/Data 1978
3. From Columns D and B
4. World Development Reports (August 1980 and August 1981) and Columns F and E
5. (i) Organización de las Naciones Unidad para el desarrollo industrial, 7 August 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

N.A. = Not Available

()* = Refinery Capacity in thousands of barrels /day

(a) UNICA Contact Man, (b) Data 80 - From "Puerto Rico in Figures 1980, GDBPR, (c) Data 1979, (d) Data 1976, (e) Data 1978, (f) Data 1979

TABLE 2

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	4b	5c	5a
St. Kitts-Nevis	NA	NA	NA	NA	NA	NA	5a
St. Lucia	1a	1a	1a	3a	2a	4a	5a
St. Vicent	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 3

NEW AND RENEWABLE ENERGY TECHNOLOGIES AND APPLICATIONS

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

REF.: Synthesis Report on the UN Conference on New and Renewable Sources of Energy.

TABLE 4

SUMMARY OF ENERGY PROJECTS IN THE CARIBBEAN REGION

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Ag
Antigua	1. Renewable Energy-Wind	Wind Generators (50-100KW)	UN Interim-F
	2. Renewable Energy-Wind	Wind Generators (12KW)	Rockefeller
	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 (200KW)	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 - Bioconersion	Alcohol Production	Brasil
	7. Renewable - Wind	Wind Turbine	OLADE
	8. Renewable Energy-Geothermal	Investigations	OLADE

TABLE 4

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
Grenada	1. Hydro	Hydrological Resource 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	Brasil
	2. Renewable Energy-Biomass	Utilization of Rice Husks	USAID
	3. Renewable Energy-Biomass	Gasification of Wood Waste, Oil-to-Charcoal conversion of alumina and bauxita kilns	IBRD
	4. Renewable Energy-Biomass	Utilization of Wood Waste	IDB/UNICEF
	5. Renewable Energy-Solar	Solar Component in the regional Program	USAID/CDB
Haiti	1. Hydro	La Chapel Hydro Project Feasibility Study	IDB
	2. Renewable Energy-Biomass	Reforestation	USAID/IDB
	3. Renewable Energy-Biomass	Appropriate Technology Center (charcoal)	USAID
	4. Renewable Energy-Biogas	Biogas Study	OAS
	5. Renewable Energy-Solar	Solar System 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

TABLE 4

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

TABLE 4

Island or Country	Project(s) and Energy Sub-sector(s)	Activity	Donor or Executing Agency
St. Vicent	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

TABLE 5

SELECTED BIOMASS ENERGY SYSTEMS

TYPE	TYPICAL FUELS	COMMENTS
A. Direct Combustion		
Energy Cane	Bagasse or bagasse pellets (co-product) to steam boiler	Cane managed for growth, not sugar. Ready for commercial scale use. Should be very competitive with No. 6 fuel oil, if cane syrup product(s) can be sold at adequate price(s).
Sugar cane	Bagasse or bagasse pellets (co-product) to steam boiler	Long history. Used extensively in Hawaii. Will not save high-cost cane operation.
Sweet sorghum		Temperate zone crop. Dropped by U.S. Dept. of Energy after extensive study.
Napier grass	Chopped hay to boiler	Tropical grass managed for growth (6 month rotation). Competitive with No. 6 fuel oil.
Sordan 70A	Chopped hay to boiler	Tropical grass managed for growth (2 month rotation). Competitive with No. 6 fuel oil.
Energy trees	Wood chips to boiler	Trees cultivated as crops. Variable rotation (2 years and up). Need more study. Economics unknown.
Agri-fuel process	Powder manufactured from cellulosic raw material.* Burned in mixture with fuel oil in conventional oil - type boiler.	Combustion in mixtures up to 50% proven commercially. Only minor modification of boiler required. Economics uncertain and sensitive to raw material characteristics. Powder readily stored and transported. Investment: $10,000/daily short ton.

Sources: (17) through (21), (33) through (36).
*By a thermo-chemical process

Table 5 (continued)

TYPE	TYPICAL FUELS	COMMENTS
Bechtel process	Mixture of chopped biomass* and powdered coal burned in conventional coal - type boiler.	Commercially reliable. Economics variable. Some loss of boiler efficiency, some environmental gain. Investment: $20,000/daily short ton.
Woodex process	Pellets manufactured from cellulosic raw material* and converted to medium BTU gas or burned directly.	Uses off-the-shelf equipment. Pellets storable. Economics variable. Investment: $5,000/daily short ton.
Wood or wood wastes	Wood chips, scraps, bark sawdust or wood-based pellets to boiler	Commercially feasible. Numerous units in operation, up to 500 MW capacity. Require forest products operations**
Municipal solid waste	Shredded combustibles to boiler	Many plants in operation worldwide. Degree of technical and economic success highly variable. Economics very site specific.
B. Anaerobic Digestion		
Animal wastes, municipal sewage sludge	Dilute solids to digestor yields biogas, residual solids and effluent.	Some successful projects in U.S. using manufactured digestors, but most require large initial investment with economics sensitive to use of residual solids. Few "off-the-shelf" small systems available yet. Millions of small, custom-made digestors in use in China and India, but economics uncertain. For MSS, see (35), p. 6.

*By a mechanical process.
**However, see (33)

TABLE 5 (continued)

TYPE	TYPICAL FUELS	COMMENTS
Sanitary landfills	Intermediate biogas (500 to 900 BTU/SCF).	Eight commercial technologies available. Economics site specific.
Water hyacinth	Wet plant to digestor yields biogass	Plant used in primary treatment of sewage. Still experimental. Collection system critical to economics.
Giant brown kelp	Wet plant to digestor yields biogas	Plant grown in sea. Affected by ocean storms. Still experimental.
C. Thermochemical gasification		
Municipal solid waste	Pyrolysis of shredded combustibles to yield pyrolysis gas (e.g. 120 BTU/SCF).	Used to generate lower pressure steam nearby. Few plants. Mixed results.
Steam gasification of wood	Methane, CO_2 and CO in proportions which depend on process parameters.	Still experimental, but promising for methane and methanol production.
D. Fermentation		
Molasses	Ethanol	Well proven processes. Best end use of ethanol is country specific.

TABLE 5 (continued)

TYPE	TYPICAL FUELS	COMMENTS
Corn	Ethanol	Well proven processes. Temperate climate crop. Economics sensitive to by product prices, source of distillation heat and process design.
E. Thermochemical liquifaction		
Methanol*	Gasoline (40%) and light hydrocarbons (50%)	Mobil process using zeolite catalyst. 13,000B/D plant under construction in New Zealand.
Wood waste	Methanol	Several experimental plants announced for N.A. and Europe.
F. Hydrolysis (for fermentation feedstocks)		
Acid hydrolysis of wood	Sugars (for ethanol)	Old technology. Maximum yield is 55% of starting cellulose by weight. Economics country specific.
Ensymatic hydrolysis of cellulosic raw materials	Sugars (for ethanol)	Still experimental. Offers possibility of large cost reduction through use of cheap raw material.

* May be obtained from biomass, coal, natural gas or naphtha. See (21) and (34), for example.

ALTERNATIVE ENERGY IN THE CARIBBEAN

by

Dr. Howard P. Harrenstien

ABSTRACT

The island communities of the Caribbean and their mainland neighbors, with the exception of Venezuela and Mexico, are suffering from increases in the price of imported fossil fuels. At the same time, these jurisdictions are blessed with an abundance of inexhaustible natural sources of energy, including solar, thermal, wind, ocean, biomass, and in certain locations, large amounts of geothermal energy. This paper reports on the progress of a project which is currently underway to develop the scientific and engineering capabilities of the universities in the Caribbean region in areas of alternative energy, under funding provided by the National Science Foundation, the Exxon Educational Foundation, the Caribbean Development Bank, and the Government of Venezuela. The project uses a unique human resource, the mechanism of the network of the Association of Caribbean Universities and Research Institutes (UNICA) to endorse a cooperative research effort aimed at increasing the capability of Caribbean institutions to assist in the introduction of alternative energy solutions into the region. An element of data collection and systems analyses of appropriate energy technology alternatives is included, with results culminating in the preparation of cooperative research and training programs to assist in the early implementation of the most economically viable alternatives. The research workshop format has been used and provisions have been made for the active involvement of a representative network of regional research centers. With coordination and leadership being provided by the Center for Energy and Environment Research (CEER) of the University of Puerto Rico, the University of Miami, the Central University of Venezuela, the University of the West Indies, and the University of Florida are all taking active roles in the assurance of the success of this activity.

ALTERNATIVE ENERGY IN THE CARIBBEAN

Howard P. Harrenstien

I. INTRODUCTION

This paper reports on the progress of an ongoing project to develop the scientific and engineering capabilities of the universities and research institutes in the Caribbean, in order that faculty, students, and staff at these institutions may assist in the orderly development of a "grass-roots" conversion to alternative energy in the region during the decades ahead. The project is funded primarily by the National Science Foundation, under their Science in Developing Countries program, and by the Exxon Educational Foundation. Additional invaluable assistance has been provided by the Caribbean Development Bank (CDB), and by the Venezuelan Government.

II. BACKGROUND AND NEED

Figure 1 shows most of the 51 inhabited islands of the Caribbean archipelago which have a total land area of about 90,000 square miles and a total population of approximately 20 million. Only one of these island-states produces fossil fuels. This is Trinidad, which has 1/45th of the total land area and 1/20th of the total 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.

The Caribbean community includes the collection of geographical entities which occur in the vicinity of the Caribbean Sea. This sea is the part of the Atlantic Ocean lying directly east of Central America; north of Panama, Colombia, and Venezuela; west of the Lesser Antilles (Leeward and Windward Islands and others) and south of Cuba, Hispaniola and Puerto Rico. The Sea is about 1500 miles long, 700 miles wide, and as deep as 22,788 feet. Ships which use the Panama Canal must by necessity pass through the Caribbean Sea, and as a result pass close to many of the Caribbean islands. Many of these

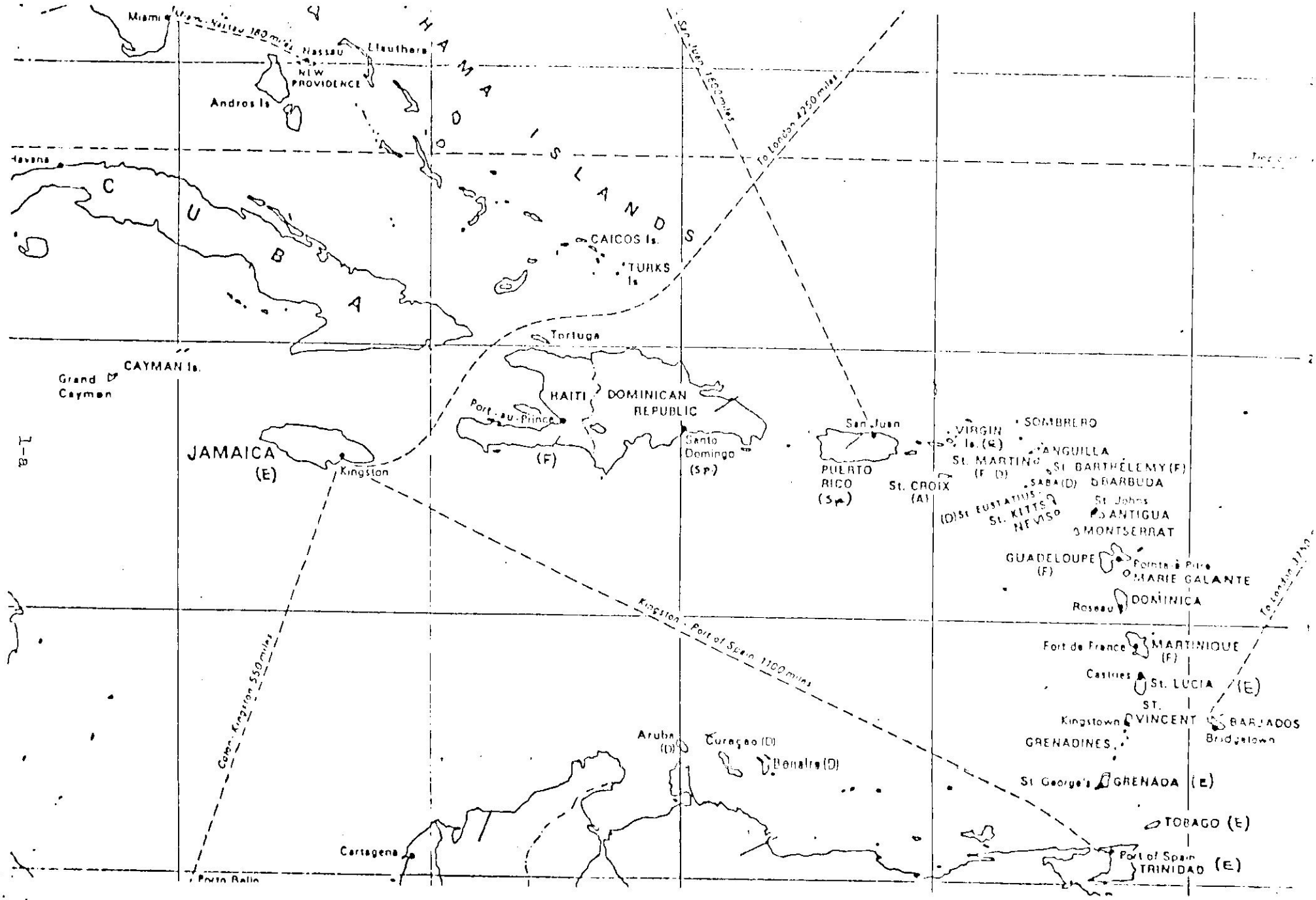

Figure 1. The Caribbean Region

islands form the West Indies, which, according to Adolf A. Berle, former Assistant Secretary of State for Latin American Affairs, is "the most strategically placed, overpopulated, ethnically complex and politically divided archipelago on earth."

Since the 1950's, the Caribbean has made strenuous efforts to diversify its economy by providing more jobs through industrilization 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 fuels.

By the end of this decade most of the archipelago will be a 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 road-blocks to progress are (a) lack of manpower, (b) inadequate research in the use of existing technology and adaptation or modification of the various technologies to the social and physical environment, (c) the lack of a grass roots cooperative energy program involving the universities and research institutes of the region, and (d) the lack of investment capital.

A system of cooperation is of great importance in a region whose history has been one of fragmentation and of dependence on external markets and external authority. The project must provide for, and depend upon, the active cooperation of universities and research institutes from the Spanish-speaking, English-speaking, French-speaking and Dutch-speaking Caribbean. The levels of research work will vary, and this requires 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 may be shared by all the institutions involved.

Its long history of elitism and of dependence on external rulers has left among many Caribbean peoples a bitter legacy of resent-

ment, even of hatred. The ideological conflicts that characterize the contemporary Caribbean and the passionate litany of abuse 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 a 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. This is why 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 reserach programs and in the preparation of a comprehensive regional program for using alternative sources of energy. Through this methods, it is contemplated that the quality of science and engineering research will be improved, and the potential for intellectual stimulation, for technology transfer and for further cooperative efforts will be realized.

The Caribbean community has a very rich potential in inexhaustible alternative energy sources. In addition to geothermal energy, which is in abundance 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, within a latitudinal range of 10°N top 25°N, has a resulting year-round solar insolation of approximately 2000 BTU per square foot per day (about twice as much as in Washington, D.C.). A few of the common solar-related resources are trade winds, ocean waves, moderate ocean currents, extensive ocean thermal masses, year-round biomass production, agriculture, mariculture, and many additional forms of solar thermal and solar electric options.

This project focuses on the need for practically all the countries of the Caribbean archipelago and Guyana to achieve greater self-sufficiency in energy; on the role that Caribbean universities and research institutes can play in meeting that need; and on the fact that the region has a rich potential in inexhaustible energy sources. We believe it represents a first indispensable step in using the existing network of research centers, schools of the 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.

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 prices of imported fuel escalate beyond 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 the deepest poverty, beyond which economic and political survival may become impossible.

III. UNICA AND THE UNICA FOUNDATION, INC.

The organization under which this project is being conducted is UNICA, which is supported by the UNICA Foundation, Inc. The principal Investigator, Dr. Juan A. Bonnet, Jr., Director of the Center for Energy and Environment Research at the University of Puerto Rico, and the Co-Principal Investigator, Dr. Howard Harrenstien, Director of Architectural Engineering at the University of Miami, are both members of the UNICA Commission for Science and Technology, with Dr. Bonnet as Chairman.

In the late 1960s, perceptive Caribbean educators saw the future development of the Caribbean community as a matter of common 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 members representing a constituency of more than 300,000 students and 30,000 faculty.

In order to lend assistance and impetus to the goals of UNICA, the Association of Caribbean Universities and Research Institutes Foundation, Inc, was created. With Dr. Henry King Stanford, retired President of the University of Miami, as President, the Foundation was established as a non-profit organization in Florida. It has been granted tax exempt status as a public charity by the Internal Revenue Service and support to the Foundation is tax deductible under the Internal Revenue Code. It is significant that the provision for alternative sources of energy and the improvement of university teaching and research in the Caribbean are among the objectives of this organization, and it is this organization which first agreed to support this project.

IV. PRELIMINARY RESOURCES ASSESSMENT

Demographic and statistical data for most of the island communities involved in the Caribbean region are contained in Table I.

As may be observed, this table presents data on the language spoken, latitude, longitude, area, population, population density, highest point, length, width, lateral exposure to wind, kwhr per person per year electrical consumption, and millions of barrels of oil per year required to generate electricity. The Table is preliminary

in nature, and must not be overestimated as to its accuracy, as its purpose is only to allow preliminary assessments to be made. Nevertheless, it is hoped that these data are found useful to those who would engage in energy analyses and projections. It is the intention of the author to continually update and expand on these data; therefore, persons who have additional or conflicting information are urged to contact him.

Table I estimated a total population among all of the islands mentioned of 18,136,800. This figure is probably somewhat low, in that 1970 statistics were used for some of the islands. The combined area of all islands is 42,213 square miles, and the estimate of combined projected shoreline which is normal to the prevailing trade winds is 827 miles. It is estimated that 37,950,000BBLS of oil per year are imported by these islands collectively to provide electrical energy to their population. If the influence of Puerto Rico is subtracted from these totals, they become 14,961,800 persons, 38,778 square miles, 737 miles, and 16,079,000BBLS of oil per year respectively.

Earlier in this conference, in the paper by Ronald D. Scott and Howard Harrenstien, a rank ordered list of alternative energy technologies which were deemd technologically suitable for development in PuertoRico was presented. If this list is reviewed for possible application to the remaining islands in the Caribbean, only slight modifications and additions need be made. The resulting list, in rank order of estimated readiness of the technology, is the following:

1. Solar Hot Water
2. Co-generation
3. Hydroelectric
4. Electricity from Solid Waste
5. Small Wind Machines

6. Large Wind Machines (Windfarms)
7. Electricity from Bagasse
8. Electricity from Solar Ponds
9. Photovoltaics
10. Ocean Thermal Energy Conversion
11. Geothermal Energy Conversion
12. Other

A preliminary estimate of the potential of these technologies as far as replacement of imported fossil fuels is concerned may be produced by assuming that the islands in the Caribbean have many similarities of character, and that lifestyles will eventually reach similar levels of industrialization and development. One can then take the current estimates of potential for Puerto Rico and use them in predicting the potential for the remaining islands in the Caribbean. Table 2 computes the values of contribution in BBLS of oil saved per year for each alternative energy technology at the end of full commercialization by the year 2000, using data which is consistent with that presented in the Scott-Harrenstein paper of reference. It may be observed that the combined contribution from the sources listed totals 154,230,000BBLS of oil per year saved. This assumes that the energy produced by the alternatives replaces electrical energy which has been produced by burning imported fossil fuel at 30% efficiency of conversion.

From Table 1, substracting the contribution from Puerto Rico, the region imports only 16,079,000BBLS of oil at the present time. If a 5% per year growth rate is assumed from 1980 to the year 2000, this total would grow to 42,662,374BBLS of oil per year. Energy self-sufficiency, then, as far as electrical generation is concerned, is achievable by the year 2000, if the Caribbean region commercializes only 27.66% of the total potential provided by alternative sources that is estimated in Table 2, as 27.66% of 154,230,000 is precisely 42,660,018.

This is very good news for this region, but a plan for orderly development and progress must be instigated at the earliest opportunity; to delay is to lose vital capital which is needed for the transition. This capital must not be spent paying for further escalating imported oil purchases, or the energy self-sufficient state may become unachievable.

As may be observed in Table 2, there are two alternatives which show significant promise for making major contributions in the immediate future. These are Wind (Numbers 5 and 6) and Biomass (Number 7). In recognition of this potential, the UNICA Commission on Science and Technology selected these for early emphasis. A progress report on the result of this activity is contained in the following section.

V. PROGRESS REPORT

The UNICA project being reported here has to date focused its activities on the collection of material related to the current state of affairs in the Caribbean with respect to alternative energy education, training, research, development and demonstration. In order to collect this material and impact the planning process for the acceleration of the introduction of alternatives into the region, it was decided to ask the universities and research institutes which comprise UNICA to appoint official contact persons who could represent their institutions, and who could participate in workshops which were designed to stimulate the production of relevant material on the subjects chosen.

1. Wind Workshop

The first opportunity for the contact persons and other invited participants to convene was at Barbados on December 6-9, 1981. A workshop was presented at that time titled "Wind

as an Energy Alternative for the Caribbean". Some 50 persons participated. After hearing background papers on the subject, the participants divided into three workshops covering the following subjects:

* Education and Training - Dr. Howard Harrenstien, Moderator
* Research and Development - Dr. Edwin Nuñez, Moderator
* Demonstration - Dr. Modesto Iriarte, Moderator

It is the opinion of UNICA that the December 6-9, 1981, Barbados Conference on Wind as an Energy Alternative for the Caribbean was a success, when seen from the point of view of evaluation by the participants, and from the point of view of providing an opening in communication links on wind energy in the Caribbean scientific and engineering education and research community. Although the three culminating workshops were conducted independently from one another, recommendations produced by them had some marked similarities and focus. A generalization of the recommendations and a prioritization results in the following conceptual overall recommendations:

1. A resource assessment should be conducted to determine the existing situation in education and training, manpower, the magnitude of the available wind resource, the availability of appropriate wind sites, and the existence of wind demonstration projects in the region.

2. Based on the results of the current "state of the art" assessment in priority #1, a plan should be prepared which would detail the steps (including costs) necessary to accomplish an acceptable level of progress toward achievement of the rest of the recommendations from the individual workshops.

3. Sources of funding should be identified which will enable the continuance of the program which was initiated by this conference and which will assure the timely completion of priorities 1 and 2.

With the achievement of these three priorities as objectives, it is predicted that the scientific and engineering capabilities of the universities and research institutes in the region will be greatly enhanced and strengthened, as far as this form of alternative energy is concerned.

The draft of the proceedings of the Barbados Wind Workshop has been prepared, and copies may be obtained by writing:

Dr. Thomas Mathews, Secretario General
Asociación de Universidades e Institutos del Caribe
Apartado Postal 11532
Caparra Heights Station
San Juan, Puerto Rico 00922

2. Biomass Workshop

The second opportunity for the UNICA contact persons to convene and to discuss the alternative energy situation in the Caribbean was in San Juan on April 28-29, 1982. The subject was "Biomass as an Energy Alternative for the Caribbean". The proceedings for this workshop are in the process of being prepared, and when completed they may be obtained from Dr. Mathews, the above source. In the interim, however, copies of some of the papers presented may be obtained directly from:

Dr. Juan A. Bonnet, Jr., Director
Center for Energy and Environment Research
GPO Box 3682
San Juan, Puerto Rico 00936

The papers which are immediately available are listed after the reference section to this paper.

VI. SUMMARY

Energy consumption patterns for the Caribbean and alternative energy assessments and analyses are a continuing activity by the research staff. Results of some of the early assessments were complied by Dr. Bonnet, and may be obtained from him at the address indicated on the preceding page.

It is clear at this stage that a much more detailed resources assessment is needed before a realistic plan for education, training, and institutional development may be prepared. In fact, it may be that through the involvement of persons in the Caribbean in the assessments and plan development, a substantial level of institutional development will occur by virtue of the grass roots nature of the activity.

What is equally clear, however, is that the Caribbean region is richly blessed with renewable alternative energy sources which are quite capable of providing energy self-sufficiency to the region in the decades ahead. Whether they do or whether they don't is a matter for responsible citizens, from both within and without the region, to immediately face; the conversion to alternative energy sources will not happen without major human and institutional effort, not the least of which is related to education, training, research, development and demonstration.

VII. REFERENCES

Macpherson, John. 1973. Caribbean Lands, a Geography of the West Indies. Third Edition. Longman Caribbean Limited, Trinidad and Jamaica.

Bonnet, J.A. 1981. The Energy Alternatives for the Caribbean. Presented at the Seminar on Wind as an Energy Alternative for the Caribbean, Bridgetwon, Barbados, December 7, 1981.

Scott, R.D. and H. Harrenstien. 1982. Alternative Energy Planning for Puerto Rico. Presented at UPADI-82, San Juan, Puerto Rico, August 3, 1982.

The International Geographic Encyclopedia and Atlas. 1979. Houghton Mifflin Company, Boston.

TABLE 1. CARIBBEAN DEMOGRAPHIC DATA

Island	Language	Latitude	Longitude	Area (sq.mi.)	Population	Population Density	Highest Point (ft)	Length (mi.)	Width (mi.)	Wind Exposure (mi.)	Electrical Consumption in 1980 kwh/person	BBls/yr for Electricity Production
Trinidad	E	10.5	61.5	1864	1,090,086	585	3085	50	30	50	1442	3.225
Tobago	E	11.0	60.5	116	46,914	404	1860	25	6	6	500 (est)	0.046
Grenada	E	12.0	62.0	120	94,000	783	2756	16	8	12	264	0.055
Grenadines	E	12.5	62.0	35	12,000	343						
St. Vincent	E	13.0	61.5	133	106,000	797	4048	20	12	17	189	0.039
St. Lucia	E	14.0	61.0	233	120,000	515	3145	26	13	20	417	0.098
Barbados	E	13.0	59.5	166	250,000	1506	1104	26	15	18	1164	0.523
Martinique	Fr	14.5	61.5	425	369,000	868	4700	38	15	38	526	0.382
Dominica	E	15.5	62.0	305	27,000	252	4672	30	12	30	206	0.031
Marie Galante	Fr	16.0	62.0	105	26,000	248		8	8	8	500 (est)	0.026
Guadeloupe	Fr	16.0	62.0	583	317,000	544	4870	30	25	30	800 (est)	0.499
Montserrat	E	17.0	62.5	39	12,700	326	3002	10	5	8	787	0.020
Antigua	E	17.0	62.0	108	69,700	645	1319	12	10	12	716	0.104
Barbuda	E	17.5	62.0	62	1,200	19						
Nevis	E	17.5	62.5	36	15,000	417	3232	8	7	8	500 (est)	0.015
St. Kitts	E	17.5	62.5	64	35,000	550	3792	22	6	22		0.053
Saba	Du	17.5	63.0	5	1,200	240	3000				500 (est)	0.001
St. Maarten	Fr/Du	18.0	63.0	14	7,000	500		10	6	6	500 (est)	0.007
Anguilla	E	18.0	63.0	35	5,000	140	200	17	3	3	500 (est)	0.005
Tortola	E	18.5	64.5	24	9,000	375		8	3	4	500 (est)	0.009
St. Croix	E	17.5	65.0	84	63,000	470	1200	25	6	10	500 (est)	--
St. John	E	18.0	64.5	20			1300	8	3	5		0.062
St. Thomas	E	18.0	65.0	28			1700	12	4	8		--
Puerto Rico	Sp	18.5	66.5	3435	3,176,000	925	4388	110	35	90	3502	21.871
Dominican R.	Sp	18.5	72.5	18,811	5,128,000	273	9000	230	100	230	539	5.434
Haiti	Fr	18.5	72.5	10,714	4,800,000	448	10,200	100	100	100	58	0.836
Jamaica	E	18.0	77.5	4400	2,100,000	477	7402	140	40	100	1014	4.189
Aruba	Du	12.5	70.0	69	61,000	884				--	1000 (est)	0.120
Curaçao	Du	12.5	69.0	180	146,000	811				--	1000 (est)	0.287
TOTALS				42,213	18,137,800					827		37.950

TABLE 2. ALTERNATIVE ENERGY CONTRIBUTIONS - CARIBBEAN ISLANDS

Alternative Energy Technology	Estimated Potential Savings in BBLs/yr by year 2000	Number of * persons	Number of * sq. miles	Number of * miles exposure	Potential Savings in * Millions BBls oil/yr by year 2000
1. Solar Hot Water	0.692 BBLs/person/yr	14,961,800			10.354
2. Co-generation	1.178 BBLs/person/yr	14,961,800			17.625
3. Hydroelectric	535.7 BBLs/sq mi/yr		38,778		20.772
4. Solid Waste	0.217 BBLs/person/yr	14,961,800			3.247
5. Small Wind Machines	0.091 BBLs/person/yr	14,961,800			1.366
6. Large Wind Machines	30,667 BBLs/mi/yr			737	22.601
7. Bagasse	1,755 BBLs/sq mi/yr		38,778		68.055
8. Solar Ponds	151.4 BBLs/sq mi/yr		38,778		5.871
9. Photovoltaic	0.290 BBLs/person/yr	14,961,800			4.339
10. Ocean Thermal (OTEC)					?
11. Geothermal					?
12. Other					?
				TOTAL	154.230

* Puerto Rico excluded. (See Scott-Harrenstien paper for Puerto Rico estimates.)

APPENDIX C

MEMBERS OF UNICA SCIENCE AND TECHNOLOGY COMMISSION

and

UNICA SCIENCE AND TECHNOLOGY COMMISSION CONTACT PERSONS

1. MEMBERS OF UNICA SCIENCE AND TECHNOLOGY COMMISSION

Dr. Juan A. Bonnet, Chairman
Director, Center for Energy and Environment Research
University of Puerto Rico
GPO Box 3682
San Juan, Puerto Rico 00936

Dr. Gerald Lalor
Pro-Vice Chancellor
University of the West Indies
Mona, Kingston 7, Jamaica

Dr. Erich Farber
Director, Solar Energy Laboratory
University of Florida
Gainesville, Florida 32611

Eng. Francisco Gutiérrez
Director, Petroleum Institute
Central University of Venezuela
Caracas, Venezuela

Dr. Howard P. Harrenstien
Department of Civil Engineering
University of Miami
Coral Gables, Florida 33124

2. UNICA SCIENCE AND TECHNOLOGY COMMISSION CONTACT PERSONS

Prof. A.M.E. Sankies
Head, Department of Mechanical Engineering
Faculty of Technology
University of Guyana, Turkeyen Campus
PO Box 101110
Georgetown, Guyana
Telephone: 69202-6, Ext. 223

Eng. Quilvio Cabral
Decano, Facultad de Ciencias y Tecnología
Instituto Tecnológico de Santo Domingo
Avenida de los Próceres, Galá
Apdo. 249, Zona 2
Santo Domingo, República Dominicana
Telephone: 566-8187

Prof. Jean-Marie Abillon
Professeur de Physique
Blvd Legitimus - B.P.771-97173
Centre Universitaire Antilles-Guyane
Pointe-a-Pitre, Guadeloupe
Telephone: 82-38-22

Dr. Gerald Lalor
Pro-Vice Chancellor
University of the West Indies
Mona, Kingston 7, Jamaica
Cable: UNIVERS
Telephone: 927-6661

Eng. Homero de Pool
Director, Escuela de Tecnología
Instituto de Estudios Superiores
Apartado Postal 59-2
Santo Domingo, República Dominicana
Cable IES
Telephone: 688-0159

Prof. Miguel S. Wionczek
Investigador Asociado
El Colegio de México
Camino al Ajusco No. 20
Apartado Postal 20-671
México 20, D.F., México
Cable: COLMEX
Telex: 1777585 COLME
Telephone: 568-6033

Prof. Julio Rivera
Decano, Colegio de Ciencias
Universidad Católica de Puerto Rico
Ponce, Puerto Rico 00731
Telephone: 844-4150

Dr. Howard P. Harrenstien
Department of Civil Engineering
University of Miami
PO Box 248033
Coral Gables, Florida 33124
Telephone: (305) 284-3356

Dr. Patrick S. Louis
Deputy Vice Dean, Faculty of Natural Sciences
University of the West Indies
PO Box 64
Bridgetown, Barbados
Cable: UNIVADOS Barbados
Telex: UNIVADOS SB 257
Telephone: PBX 02191

Lic. Antonio Fernández
Departamento de Física
Universidad Nacional Pedro Henríquez Ureña
Santo Domingo, República Dominicana

Dr. Robert L. Sullivan
Department of Electrical Engineering
University of Florida
Gainesville, Florida 32611

Dr. Michael Canoy
Caribbean Research Institute
College of the Virgin Islands
St. Thomas, U.S. Virgin Islands 00801
Telephone: (809) 774-1252

Professor S. Satcunathan
Faculty of Engineering
University of the West Indies
St. Augustine, Trinidad
Cable: STOMATA Port of Spain
Telephone: 662-7171

Eng. Nelson Gil Gil
Dean, Faculty of Engineering Sciences
Universidad Católica Madre y Maestra
Santiago de los Caballeros
República Dominicana

Dr. Juan A. Bonnet, Jr.
Director, Center for Energy and
Environment Research
University of Puerto Rico
GPO Box 3682
San Juan, Puerto Rico 00936
Telephone: 765-7210

APPENDIX D

Report on

Wind as an Energy Alternative for the Caribbean Workshop

Barbados, December 6-9, 1981

UNICA Commission on Science and Technology

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

SUMMARY REPORT

It is the opinion of UNICA Science and Technology Commission that the Dec. 6-9, 1981 Barbados Workshop on Wind as an Energy Alternative for the Caribbean was a success, when viewed from the point of view of evaluation by the participants, and from the point of view of providing an opening in communication links on wind energy in the Caribbean scientific and engineering educational and research community.

Although the three culminating workshops were conducted independently from one another, recommendations produced by them had some marked similarities and focus. All three reports are included here. A generalization of the recommendations and a prioritization results in the following conceptual overall recommendations.

1. A resource assessment should be conducted to determine the existing situation in education and training, manpower, the magnitude of the available wind resource, the availability of appropriate wind sites, and the existence of wind demonstration projects in the region.

2. Based on the results of the current "state of the art" assessment in priority #1, a plan should be prepared which would detail the steps (including costs) necessary to accomplish an acceptable level of progress toward achievement of the rest of the recommendations from the individual workshops.

3. Sources of funding should be identified by the UNICA Foundation which will enable the UNICA Commission on Science and Technology to continue the program which was initiated by this conference, and which will assure the timely completion of priorities 1 and 2.

With the achievement of these three priorities as objectives, it is predicted that the scientific and engineering capabilities of the universities and research institutes in the region will be greatly enhanced and strengthened, as far as this form of alternative energy is concerned.

The UNICA Science and Technology Commission stands ready to assist as a mechanism through which the above may be accomplished, and by which UNICA member institutions may better service the communities in which they are located for the overall betterment and improvement of the entire region in this "grass roots" type of Caribbean development initiative.

As a Commission we are deeply grateful for the generous support which has been given by the National Science Foundation, the Exxon Education Foundation, the UNICA Foundation, the Caribbean Development Bank and the UNICA staff.

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP
Barbados, December 6-8, 1981

WORKSHOP SESSION, GROUP NO. 1

EDUCATION AND TRAINING NEEDS

Report by

Dr. Howard Harrenstien, Moderator

General

This workshop session was attended by 15 persons representing nine countries:

1.	Guilvic Cabral	Dominican Republic
2.	Román S. Cristóbal	Dominican Republic
3.	Homero Pool	Dominican Republic
4.	Michel DuPont	Guadeloupe
5.	Jessel Edwards	Antigua
6.	Hopeton Gordon	Guyana
7.	Howard Harrenstien	Florida, USA
8.	Elvet Hughes	Anguilla
9.	Robert J. Martin	Puerto Rico
10.	Paul Neua	Barbados
11.	Renato Núñez	Dominican Republic
12.	José B. Rodríguez	Dominican Republic
13.	S. Satcunanathan	Trinidad
14.	Luciano Sbriz	Dominican Republic
15.	Robert Sullivan	Florida, USA

To stimulate discussion, the workshop specifically addressed three general questions as related to wind energy education and training acitivites in the Caribbean, noting regional differences where possible. The three questions were:

(1) What has been done in wind energy education and training in the Caribbean?

(2) What should be done in wind energy education and training in the Caribbean in the future?

(3) What is the mechanism by which it may be accomplished?

To gain an understanding of the general state of affairs in energy education and training in the region, as regards the present and needs for the future, a poll was conducted of the participants to determine their assessment of these conditions. The results of the poll are noted in Table 1. It may be observed that the participants rated an average score of 2.9 which is equivalent to "little activity" for the present state, and a score of 1.5 which is between "moderately" and "very active" for the desired future state.

From this poll and the discussion which ensued, it was concluded that the entire region needed to strengthen its educational and training programs along subject lines listed in the categorical activity headings of Table 1. These categories are the following:

(1) Engineering education programs at the baccalaureate Level.

(2) Science education programs at the high school and university levels.

(3) Continuing education programs at the professional level.

(4) Community education and training programs at the consumer and technician level.

(5) Scientific community education at the high school and university teacher level.

(6) Modification of high school and university curricula to place increasing emphasis on alternative energy related subjects.

(7) Videotape information dissemination through television network programming.

(8) Cooperative educational programs which place educational emphasis on industrial experiences.

Recommendations

The workshop prepared specific regional recommendations as a result of discussions which took place. These recommendations are the following:

(1) A resource assessment should be conducted to determine existing capability in alternate energy education and training in the region.

(2) Scientific and technical requirements should be determined to facilitate a viable wind energy utilization program in the Caribbean. Specifically, a study should be performed to determine the educational and training requirements for the region in wind energy.

(3) A program should be developed to add to the capability noted in recommendation #1 to meet the requirements outlined in recommendation #2.

(4) Encourage active involvement of regional institutions in carrying out recommendations #1-3.

(5) UNICA should sponsor regular meetings whereby university faculty, researchers, and education and training specialists can assess the status of completing recommendations #1-4.

(6) Liberal use of the following mechanisms should be used to accomplish the necessary educational and training mission:

Short courses
Institutes
Fellowship programs
Correspondence courses
Curriculum development packages
Post-doctoral programs
Sabbaticals
Symposia and conferences
Faculty and researcher exchanges
Videotapes of demonstrations and applications

(7) A focal point for coordinating laboratory, training and instrumentation needs in the Caribbean should be created. This should include university coordination, inventory of personnel and equipment, and the cataloging of available industrial and governmental assistance. UNICA should be this focal point, with the actual performance to be done under the granting mechanism.

In addition to the general recommendations above, a few participants submitted detailed comments and recommendations pertaining to their specific countries. They are the following:

Dominican Republic -- Núñez, Román, Rodríguez, DePool, Sbriz

(1) What is being done in the Dominican Republic about making the general public aware of energy problems?

(a) The National Commission on Energy Policy has a sizeable program of seminars, conferences and courses, in which the world energy situation and the country's in particular are explained and analyzed.

(b) The Dominican Corporation of Electricity maintains a publicity campaign through radio, press, and TV in which

the public is called on to economize electrical energy and through which is announced what the country spends on petroleum and what this cost signifies in relation to the national estimate.

(c) Places of higher education, universities and institutes offer courses and seminars to their members in which are presented actual problems relating to energy problem.

(d) Institutionalize the financing of housing to offer incentives to clients to use solar heaters instead of electric ones.

(2) What should we do in addition?

(a) Promote the idea within the higher education system to offer graduate courses and/or masters degrees relating to the management of energy resources.

(b) Suggest to these same systems to introduce a mandatory course on problems relating to energy in all of their professional programs in technical areas and at the same time taking into consideration energy problems in the courses of the programs which in one way or another treat these same problems.

(c) Influence university students so that their theses treat specific problems of the country relative to the area of energy.

(d) Orient the appropriate technological investigations through channels directed to make a more rational use of the energy resources of the country, trying where possible to minimize the use of the imported and maximize use of the native.

(e) To make those with decision-making power in the government conscious of energy problems so that they take them into consideration when formulating government plans.

(f) Create educational campaigns in the secondary schools to start guiding students at this level on this matter.

(g) Offer ample facilities to rural areas to install windmills for their use in obtaining the necessary water for their communities.

(3) How can we make this campaign a reality, what can we count on and what do we need for this?

To bring this campaign into reality we count on institutions involved with the transformation of energy, and others dealing with the management of energy resources who feel the closeness of the world crisis of these resources. However, their influence on government officials is not enough and their available means to bring to fulfillment educational programs is very limited.

In short, we can presume that to bring an ample educational program that correctly informs on the reality of these problems, we need financial resources and the necessary personnel, capable and conscious of the significance of these problems to the future of our country.

TABLE 1

Activity	Dominican Republic		French West Indies		North Central Florida		Guyana		Trinidad & Tobago		Average	
	Now	Future	Now	Future	Now	Future	Now	Future	Now	Future	Now	Future
1. Engineering Education Programs	3	2	4	1	1	1	2	1	1	1	2.2	1.2
2. Science Education Programs	4	2	4	2	1	1	3	1	-	-	3.0	1.5
3. Continuing Education Programs	2	2	4	1	2	1	3	1	2	1	2.6	1.2
4. Community Education Programs	2	1	3	1	2	2	3	1	4	2	2.8	1.4
5. Scientific Community Education Programs	4	2	3	2	2	2	4	1	2	2	3.0	1.8
6. Curriculum Modification Programs	4	2	4	3	2	2	3	1	2	1	3.0	1.8
7. Video Tape Information Programs	4	3	4	2	2	1	4	1	4	2	3.6	1.8
8. Cooperative Educational Programs	3	2	4	1	3	2	4	1	2	2	3.2	1.6
9. Average	3.3	2.0	3.8	1.6	1.9	1.5	3.3	1.0	2.1	1.4	2.9	1.5

CODE: 1 - Very active
2 - Moderately active
3 - Little activity
4- No activity

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP
Barbados, December 6-8, 1981

WORKSHOP SESSION, GROUP NO. 2

RESEARCH AND DEVELOPMENT NEEDS

Report by

Dr. Edwin Nuñez, Moderator

General

This workshop session was attended by eleven persons representing ten countries.

1.	Edwin Núñez	Puerto Rico
2.	Melvin Sankies	Guyana
3.	Sixto Wout	Curacao
4.	Stephen Lamming	Barbados
5.	Lester Nelson	Grenada
6	Joseph Daniel	Montserrat
7.	Michael Canoy	U.S. Virgin Islands
8.	Richard L. Simon	California, USA
9.	José B. Rodríguez	Dominican Republic
10.	Majaraj S. Tomar	Venezuela
11.	David S. Renne	Washington, USA

I. RESEARCH AND DEVELOPMENT--SEPARATE VS. UNIFIED APPROACH

A glimpse of a map of the Caribbean region will show a great assortment of island-countries with diverse cultures and languages. Upon closer scrutiny, this first impression will be transformed and attenuated by the realization that there are many common goals and aspirations. Each country is striving to give a maximum number of its citizens a high standard of

living without creating major environmental damage or exacerbating social tensions. By the same token, they share similar problems and obstacles which hinder their development. In general, the islands are very small sized with large population densities, have scant natural resources and the sea acts as an imposing barrier which impedes communications and access to the outside world.

Before the Caribbean countries elaborate specific energy research and development policies, they must decide whether their interests will be pursued separately or through a unified approach. The latter alternative implies the pooling of resources by different countries. Criteria such as proximity, common language, complementarity of their resources or previous cooperation experiences might induce countries to unite in one or more groups. Table I presents some of the advantages and disadvantages resulting from Caribbean countries working separately or unified in the elaboration and implementation of their energy research and development policies.

It is the belief of the participants of the research and development needs workshops that the advantages of a unified approach far outweigh the disadvantages. Consequently, Caribbean universities, governments and institutions dealing with R&D should make an effort to establish one or more regional groups in which individual countries can contribute their resources to complement each other's weaknesses.

II. RESEARCH AND DEVELOPMENT -- CONSTRAINTS

Caribbean countries, utilizing different philosophies to address their idiosyncracies, are striving to achieve development in the shortest possible interval of time. In a world that gets more complex every day this endeavor becomes increasingly difficult. R&D is much harder to undertake in these countries than in industrialized nations.

Workshop participants agreed on the following list as the most important impediments to their R&D efforts.

(1) Isolation - Quite often, the scientist or engineer finds that he is the only person in the country or institution which has advanced specialized knowledge in a particular field (e.g., wind turbine design). Very little opportunities exist to share his ideas with other specialists in his field. Libraries lack the most current journals or books.

(2) Lack of Infrastructure - The infrastructures necessary to deploy, operate and maintain a new technology are frequently nonexistent.

(3) Overinvolvement - Being one of the very few technically trained people in a country means that a large number of people will request his involvement in a wide variety of projects. Restricted attention will likely be given to each project resulting in meager progress and results. Many times he has to work in areas which are outside his field of expertise.

(4) Finances - Governments allocate scant resources for R&D needs since they respond to the pressures exerted by groups which have more political leverage than scientists and engineers. Financial restrictions oblige scientists to leave many areas of a particular problem untouched.

(5) Government and Civil Inertia - Governments show little understanding of the importance of R&D activities in a developing country. New techniques are usually received with skepticism and resistance by the civil population of a country.

(6) Lack of Peer Participation - Many of the organizations which disburse R&D funds in the Caribbean do not have

proper participation of scientists and engineers. Funds are allocated by people who lack a real understanding of R&D.

III. RESEARCH AND DEVELOPMENT -- NEEDS

Wind has the potential of becoming an important alternative energy source for the Caribbean basin. It was agreed that the following areas need immediate attention in order to realize that potential in the near future.

(1) Before wind turbines can be deployed on a wide basis in the Caribbean, each island must have detailed knowledge of its wind resource.

(2) Siting studies have to be conducted in order to search for the best locations to install both large and small scale wind turbines.

(3) Evaluation of existing technology and the development of adaptations which might suit local needs.

(4) Operations and maintenance research in order to test materials resistance to salt corrosion, hurricane winds.

(5) Testing of local wind turbine designs and adaptations.

(6) Research on the economic and social impact of new technologies.

(7) Evaluation of existing energy production and utilization systems to achieve energy savings through conservation and second-law efficiency considerations. This offers the potential saving the greatest amount of energy in the shortest interval of time.

IV. RECOMMENDATIONS

In order to satisfy the aforementioned R&D needs, the workshop participants make the following recommendations to UNICA, CDB, CARICOM, and any other agencies dealing with the development of the region:

(1) Top priority should be given to wind resource assessment proposals and wind siting studies. Within a period of four years, all Caribbean islands should know their aeolic resources.

(2) Projects and studies should be funded which consider the economic, social and legal impact of alternative energy systems, in particular wind turbines.

(3) It is deemed important to sponsor projects which use an integrated systems of energy approach such as solar/biomass, wind/hydro, wind/solar, etc. The domestic, industrial and agricultural applications suited to the particular country's milieu should be explored.

(4) Research in the problems associated with the operations and maintenance of alternative energy systems should be undertaken. Special attention should be given to the problems associated with materials and parts resistance to salt corrosion and protection from hurricane force winds.

(5) Local wind turbine designs and adaptations should be encouraged. Development projects whose purpose is to establish the manufacture of wind turbines and other alternative energy systems within the region should also be encouraged.

(6) The active participation of scientists and engineers in the boards and committees of institutions which disburse

R&D funds in the Caribbean is considered essential. The peer review method is recommended for the evaluation of all proposals and publications.

(7) Priority should be granted to projects which explore the energy production and utilization systems. Energy conservation and second-law efficiency projects offer the potential of saving vast amounts of energy in the region.

(8) A survey should be conducted of the available human resources in the region with expertise in the energy R&D areas. After the survey is conducted a human resources and project directory should be published and an institution or institutions should be designated as clearing-house for locating expert resources in each area (wind, biomass, solar, etc.). Any similar efforts which have already been undertaken in the region should be more readily available. A greater awareness of what others are doing or have done is needed.

(9) Conduct regional seminars on fund availability and on the proper techniques for the preparation of proposals to be submitted to the regional development agencies. An institution or institutions could be designated as clearing-house of this information.

(10) It is strongly recommended that, whenever possible, alternative energy development meetings for the region take the workshops format similar to the present UNICA meeting. The conference should discuss openly what are considered to be the successes and failures. Reports should be written and published so that conference results are widely available.

Abstracts of papers to be given at a conference should be available with sufficient time before the meeting. Pros-

pective participants can decide wisely on that basis whether to attend or not.

(11) It is felt that the use of wind as an energy alternative for the Caribbean can be accelerated if programs are designed by the development agencies which convince governments of:

(a) the necessity of granting tax incentives to people who install a wind turbine.

(b) allowing the individual consumer to sell energy produced by a wind turbine to the power company (similar to PURPA in the United States).

(12) Projects designed to create the appropriate infrastructure necessary for R&D and for the deployment operation and maintenance of wind turbines should be funded.

TABLE 1 Advantages and Disadvantages resulting from Caribbean countries elaborating and implementing their energy research and development policies separately or unified.

Mode	Advantages	Disadvantages
Separate (each country having an individual approach)	Country can pinpoint its own R&D needs very precisely and work on them	Higher cost to each individual country
	Country can proceed at its own pace without being bound by others	Lack of technical and human resources will probably require more intensive foreign (outside of Caribbean) participants
Unified (groups of countries working together)	Cost savings. Pooling of resources will mean lower planning, equipment and data analysis costs	Potential political problems
	Countries can complement each others necessities by sharing their human and technical resources	Delays in getting done due to the necessity of allocating limited resources to various countries
	Region-wide spirit of cooperation	
	Possibility of pooling together to purchasing alternative energy systems (wind turbines, digestors, etc.) at a reduced price	

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP
Barbados, December 6-8, 1981

WORKSHOP SESSION, GROUP NO. 3

DEMONSTRATION NEEDS

Report by

Dr. Modesto Iriarte, Moderator

General

This workshop was attended by eight persons representing six countries:

1.	Cristóbal Román S.	Dominican Republic
2.	Luciano Sbriz	Dominican Republic
3.	Jim Sparks	St. Lucia
4.	Oscar Guzmán	Mexico
5.	Peter Williams	Barbados
6.	T.S. Anderson	USA
7.	J. Bellimore	Barbados
8.	Modesto Iriarte	Puerto Rico

It was found that each country has different demonstration projects in wind power uses, but that they were unaware of each other's activities. It is suspected that the same problem of lack of communication and flow of information between other nations in the Caribbean not represented at this workshop exists.

It was further stated by the group participants that each country has its own particular needs and that therefore identification of future demonstration needs will be appropriate after these needs are taken into consideration. Local needs in many areas take into consideration such things as oil displacement needs, isolated community needs, the needs of electric power for solving critical needs

such as providing energy to operate certain sanitary and health facilities as well as other social needs, legal problems involving generation restrictions for personal use and or sale. In St. Lucia, for example, nobody can generate its own electricity without violating social laws. This represents an obstacle to WTG development.

The group generally concurred that wind power assessment programs in the various areas should be encouraged and that small demonstration projects should be developed as soon as practicable and/or in parallel with assessment.

Recommendations

In order to address the subject of demonstration needs, the group recommended that an inventory of existing demonstration projects in the area be first made. The purpose of this inventory compilation are:

(1) to prevent duplication of efforts.
(2) to provide asssistance with data base.
(3) to give funding agencies information on projects needing funding and projects which have been funded by others.
(4) to provide a working base for future projects.
(5) to give directions for future developmental thrusts.

In order to carry out the above recommendations a questionnaire should be prepared. A suggested questionnaire is as follows:

Typical information needed:

Country and agency involved, contact person

Location of unit:
(a) are maps available?
(b) are photographs available?

Purpose of unit:

(a) water pumping
(b) electricity production
(c) mechanical
(d) other

Designer of unit:

(a) manufacturer of unit
(b) designer (if unit locally built)
(c) level of local component in design and manufacture of unit

If locally built, are plans or report available?

Funding Agency:

(a) privately owned
(b) government funded
(c) funded by outside source
(d) other

Is wind data available?

(a) at site location
(b) at other locations

Condition of unit:

(a) under construction
(b) working
(c) needs repair
(d) planning stages

If working, performance of unit:

(a) details

If needing repair:

(a) advantages to repair
(b) estimation of cost
(c) details

If in planning, has funding been acquired?

Identify type of future demonstration projects needed in the area:

(a) estimation of cost
(b) planning requirements
(c) possible funding agencies
(d) specific help you would like to secure

Short-term objectives

A set of short term objectives (say for 6 months accomplishments) was outlined by the group participants as follows:

(1) Catalog existing wind turbine installations.

(2) Pursue the reactivation of abandoned wind turbine projects.

(3) Removal of obstacles to wind turbine development; study legal problems in different areas.

(4) Rate structure consideration from wind sources.

(5) Identify incentives to promote wind turbine development.

(6) Emphasis should be placed on turbine systems that can be manufactured locally.

Engr. Cristóbal Román from CDE, Dominican Republic, suggested and the group unanimously agreed that a simple procedure to make the inventory be followed consisting of:

(1) preparing the questionnaire

(2) mailing it to the various contact people and those attending this symposium

(3) receiving and summarizing data (he offers himself, but feels UNICA should do it).

(4) travel to those areas in arrears in returning the information questionnaires.

Organization

An organization of one project coordinator under UNICA staff, using available UNICA staff services such as office, secretary, communication and reproduction, is proposed. This coordinator would identify a contact man in each of the areas from whom he will obtain the information.

The information will be gathered, reduced, and published. A follow up or updating action every year should be attempted.

Benefits

This information would provide a data base for the various countries to reduce duplication efforts, to be in a better position to present proposals for requesting funds for their projects. Other aspects in which this activity could help would be in accelerating the development and use of wind power, the pricing and costing of power produced, determining appropriate sale back prices of electricity to local utilities, etc.

This information would identify the difficulties and failures of the existing demonstration projects and provide guidance in instrumenting procedures for documenting and reporting the operation of demonstration projects.

Funding

The group's opinion is that funding should be addressed jointly from the identified needs of the three workshop groups. However, for purposes of budgeting it can be estimated that this job should be assigned at least 5 man-years for the project coordinator plus travel expenses, plus 5 man-years secretarial services in addition to overhead costs of office, telephone, reproduction, etc.

Additional manpower is required for the contact persons. It is recommended that this cost be borne by the local interest groups or local governments.

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP
Barbados, December 6-9, 1981

EVALUATION

At the close of the workshop, an evaluation questionnaire was given to each participant to elicit their reactions to this type of activity and to obtain individual recommendations for improvement or modification of similar future conferences. The tabulated results of this evaluation exercise are attached hereto.

As the tabulation shows, the majority of respondents (77%) gave an overall rating of "Good" (one step below the maximum "Excellent") to the workshop. It is also worth noting that the group discussion format received the highest percentage (55.2%) of "Excellent", while the question on speakers got the lowest "Excellent" percentage (13.8%). Another interesting finding is that 17.2% of respondents indicated that they were unaware of the UNICA Project goals.

These and other observations, criticisms and suggestions will be taken into consideration in the organization of future workshops, in particular the biomass workshop scheduled for the spring of 1982 in San Juan, Puerto Rico under the UNICA Project.

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

EVALUATION

Question	Number	Percent
1. Organization and Logistics		
Excellent	8	27.8%
Good	17	58.6%
Fair	4	13.8%
Poor	0	0
2. Speakers		
Excellent	4	13.8%
Good	21	72.4%
Fair	4	13.8%
Poor	0	0
3. Workshop Discussion		
Excellent	16	55.2%
Good	13	44.8%
Fair	0	0
Poor	0	0
4. Overall		
Excellent	6.5	22.4%
Good	22.5	77.6%
Fair	0	0
Poor	0	0
5. How successful was the workshop in meeting the goals of the UNICA Project?		
Very successful	6	20.7%
Successful	11.5	39.7%
Somewhat successful	3.5	12.1%
Not successful	1	3.4%
Unaware of the UNICA Project's goals	5	17.2%
Other answers	1	3.4%
No answers	1	3.4%
TOTAL RESPONDENTS: 29		

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP
BARBADOS - DECEMBER 6-9, 1981

SUNDAY – DECEMBER 6

10:00–12:00 AM
REGISTRATION
Holiday Inn, Barbados

12:30–2:30 PM
LUNCHEON
University Presidents, Barbados Hilton

3:30–4:30 PM
WELCOME
Dr. Hugo Sánchez Medina
President of UNICA
Dr. Henry King Stanford
President of UNICA Foundation
Dr. Juan A. Bonnet, Jr.
Chairman of UNICA
Commission for Science and Technology

5:30–7:30 PM
COCKTAIL
Hosted by the U.S. Information Service
and the Venezuelan Consulate

MONDAY – DECEMBER 7

MORNING SESSION
Dr. Jeffrey Dellimore (Moderator)

9:00–9:30 AM
The Energy Alternatives for the Caribbean
Dr. Juan A. Bonnet, Jr.
Center for Energy and Environment Research

9:30–10:00 AM
Wind as an Alternative Energy Source
Dr. Howard P. Harrenstein
University of Miami

10:00–10:30 AM
COFFEE BREAK

10:30–11:00 AM
Wind Monitoring Systems
Mr. Richard L. Simon
Pacific Gas and Electric Co.

11:00–11:30 AM
Wind Potential for the Caribbean
Mr. Steven Lamming
Caribbean Metereological Inst.

11:30–12:00 AM
DISCUSSION

12:00–1:30 PM
LUNCH AND SPEAKER
Mr. Pablo Ligari
Centro La Gaviota, Bogotá, Colombia

AFTERNOON SESSION
Mr. Theodore S. Anderson (Moderator)

1:30–2:00 PM
Resource Assessments and Siting Techniques
Mr. David Renne
Batelle-Pacific Northwest Laboratory

2:00–2:30 PM
Small Wind Energy Conversion Systems
Dr. Jorge Zatt
Centro La Gaviota, Bogotá, Colombia

2:30–3:00 PM
Large Wind Energy Conversion Systems
Mr. William Vachon
Arthura D. Little, Inc.

3:00–3:15 PM
DISCUSSION

3:15–3:45 PM
COFFEE BREAK

WORKSHOP SESSIONS
Mr. William Ocasio (Moderator)

3:45–4:15 PM
WORKSHOP ORGANIZATION

4:15–6:00 PM
WORKSHOP GROUPS: DISCUSSION

TUESDAY – DECEMBER 8

8:00–10:00 AM
WORKSHOP GROUPS: DRAFTING AND REPORTS

10:00–12:00 AM
WORKSHOP:
PRESENTATION AND DISCUSSION OF RESULTS

AFTERNOON SESSION

2:00–4:00 PM
WORKSHOP: FINAL REPORT PREPARATION

4:00–5:00 PM
PLANNING FOR THE FUTURE
UNICA Contact Persons

WEDNESDAY – DECEMBER 9

7:00–9:00 AM
FUTURE ASSIGNMENTS BREAKFAST MEETING
UNICA Commission Members

WORKSHOP BREAKDOWN

Group 1 – EDUCATION AND TRAINING
Dr. Howard P. Harrenstein,
University of Miami

Group 2 – RESEARCH AND DEVELOPMENT NEEDS
Dr. Francisco Gutierrez,
Univ. Simón Bolívar, Venezuela

Group 3 – DEMONSTRATION NEEDS
Dr. Modesto Iriarte,
Center for Energy and Environment Research

APPENDIX E

Report on

Biomass as an Energy Alternative for the Caribbean
Workshop

San Juan, Puerto Rico

April 28-29, 1982

UNICA Commission on Science and Technology

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

SUMMARY REPORT

It is the opinion of the UNICA Science and Technology Commission that the April 28-29, 1982 San Juan Workshop on Biomass as an Energy Alternative for the Caribbean was a greater success than the first Workshop on Wind because of many circumstances. Some of the most favorable conditions were the familiarity of the UNICA contact persons among themselves and with the project, which stimulated a direct interest in their involvement and commitment to its success. Also the workshop followed the Fuels and Feedstocks for Tropical Biomass II Seminar which provided the UNICA contact persons unique opportunity to become acquainted with the subject.

Again, following the format of the Wind Workshop, the group was separated in three working sessions: Education and Training Needs. Research and Development Needs, and Demonstration Needs.

It may be gathered from the recommendations that biomass is perceived as one of the energy alternatives for the Caribbean which could be utilized faster based on the agricultural experience and knowhow of the region. Consequently, a generalization of the recommendations can be formulated as follows:

(1) Securing funding to establish research, development and demonstration projects of specific nature in the region on biomass as an energy source should have the highest priority.

(2) In order to implement the above recommendation, education and training programs to prepare the human resources needed in tropical biomass for the region are a must.

(3) UNICA should play a vital role in technology information, disseminating, R&D projects evaluation and technology transfer between their member institutions.

(4) The UNICA Foundation role of securing funds for implementation the above is essential and indispensable to carry out such programs.

If the above recommendations are implemented the science and engineering capabilities of UNICA member institutions in biomass matters would be greatly enhanced. Also, the role of the universities and research institutes as providers of solutions to society problems would be strengthened.

The UNICA Science and Technology Commission wishes to thank all the UNICA contact persons for their participation in their workshops and in particular the moderators of the session who drafted the workshop reports. Also, we are deeply grateful for the funding support from the National Science Foundation, Exxon Education Foundation and the UNICA Foundation.

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

San Juan, P.R., April 28-29, 1982

WORKSHOP SESSION, GROUP NO. 1

EDUCATION AND TRAINING NEEDS

Report by

Dr. R.L. Sullivan, Moderator

General

Participants in the Education and Training Workshop session included:

Dr. Jairo Lascarro (University of Puerto Rico)
Eng. Gerardo Manan Paniagua (INTEC, Dominican Republic)
Mrs. Lourdes Iturralde (Universidad Simón Bolívar, Venezuela)
Mr. William Chalmers (Caribbean Development Bank, Barbados)
Dr. Glenda S. O'Brien (University of the West Indies, Jamaica)
Mr. Gerald Lalor (University of the West Indies, Jamaica)
Dr. R.L. Sullivan (University of Florida, USA)

Recommendations

(1) UNICA should decentralize the work of the Commissions into technology working groups and increase the number of contact people.

(2) To fund the increased activity stemming from the new structure UNICA should actively seek new additional funding for a three year budget.

(3) Each working group should be encouraged to submit budgeted

proposals to the appropriate Commission to fund specific activities e.g., workshops, continuing education programs, etc.

(4) Each working group should establish communications and data collection procedures.

(5) UNICA should fund exchange programs among Caribbean universities as a means for improving the transfer of new technology knowledge in the region.

(6) UNICA should sponsor a special workshop on education with emphasis on university curriculum development and communication techniques aimed at improving the region's awareness of the various new technology options.

(7) Each working group should publish an edited volume describing the state of the art of its specific technology for each country in the region.

(8) Each working group should be responsible for promoting its specific area of concern within the Commission.

(9) Video cassettes should be made for each technology to promote its development and use among teachers and public officials.

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

San Juan, P.R., April 28-29, 1982

WORKSHOP SESSION, GROUP NO. 2

RESEARCH AND DEVELOPMENT NEEDS

Report by

Dr. Al Binger, Moderator

General

It is the general view of the working group that there is a great need for collaboration and exchange of technological know-how between member institutions. It is felt that UNICA must address itself to the development of a mechanism to allow for such transfer. It is also commonly felt that there exists in the region various technologies which are needed in other countries.

The efficiency of UNICA members is being affected by:

(1) Inadequacies in the procurement and dissemination of information

(2) Obstacles preventing collaboration between regional institutions.

UNICA could be an efficient organization in the development and propagation of science and technology in the region if it could overcome some of these problems.

Research and Development

These are short term recommendations aimed at stimulating developmental work for various UNICA members and at addressing certain problems which some members are presently having.

We interrelate our project goals in energy with those for the protection of the environment and construct our project proposal in order to take advantage of all funding which exists in other areas such as environment protection, agriculture, etc. Attempts should be made to have joint projects developed whenever possible, realizing that projects must be specific nature for the sites involved. One of the main potentials seems to be for the utilization of cocoa and coffee waste in generating biomass. We should recognize that duplication can be both good and bad. However, duplication should result in more efficient use of funds.

Wherever possible UNICA should speed up the distribution of funds coming into the region for R&D and whenever time allows before importing foreign technology we ask UNICA personnel if such technology had been previously tested in the region and with what result. Projects aimed at utilizing biomass as chemical feedstocks should be given priority. The orientation of such projects is more technologically and financially demanding but they are potentially more feasible. It is therefore recommended that all such projects be undertaken in collaboration.

The UNICA representative in each country, after consulting with his colleagues, should identify the areas of research and development with specific input and submit these to UNICA for processing. Hopefully this will provide a current assessment of energy R&D in the region.

A techno-economic evaluation unit should be established to provide this service for cost-benefit analysis so as to deduce the benefit of project. In developmental work, all pertinent data from the region should be supplied so as to allow analysis for site and regional applicability and potential. That U.S. AID policies in the region should be evaluated to see how they promote:

(a) regional collaboration
(b) developing expertise within the region

As there is a present funding shortage, it is suggested that UNICA solicit funds in an effort to act as a source of interim financing for collaboration projects with regional application.

Closer working contacts should be maintained with research and dvelopment institutions in the region as these institutions usually have more funds, personnel and equipment to assist the developmental phase of projects. UNICA would therefore seek funding for the actual development of collaboration of regional projects.

We accept the offer of collaboration from French Overseas University Programs offered by Professor J. Renoux of AUPELF. UNICA should make representation to funding agencies for funds to aid in organizing this information service and to provide the required training to allow the transfer of technology from this source to the countries where it can be utilized.

Until an information machinery is in place for the dissemination of information, person-to-person communication should be undertaken. Since the existing questionnaire is viewed as being difficult to comply with, it is suggested that each person supply his present project with his immediate needs for information and funding in order that UNICA Secretariat can provide whatever short term assistance it can.

UNICA should include in its current publications a section on research projects stating: institution, persons, projects in progress and current status, projects in planning, projects in which institutions are seeking collaboration, funding availability and requests for assistance from members. This will allows UNICA contact persons to be aware of funding availability for research and distribute this information to people whom they think can benefit from this.

As there is a present funding shortage, it is suggested that UNICA solicit funds in an effort to act as a source of interim financing for collaboration projects with regional application.

Closer working contacts should be maintained with research and dvelopment institutions in the region as these institutions usually have more funds, personnel and equipment to assist the developmental phase of projects. UNICA would therefore seek funding for the actual development of collaboration of regional projects.

We accept the offer of collaboration from French Overseas University Programs offered by Professor J. Renoux of AUPELF. UNICA should make representation to funding agencies for funds to aid in organizing this information service and to provide the required training to allow the transfer of technology from this source to the countries where it can be utilized.

Until an information machinery is in place for the dissemination of information, person-to-person communication should be undertaken. Since the existing questionnaire is viewed as being difficult to comply with, it is suggested that each person supply his present project with his immediate needs for information and funding in order that UNICA Secretariat can provide whatever short term assistance it can.

UNICA should include in its current publications a section on research projects stating: institution, persons, projects in progress and current status, projects in planning, projects in which institutions are seeking collaboration, funding availability and requests for assistance from members. This will allows UNICA contact persons to be aware of funding availability for research and distribute this information to people whom they think can benefit from this.

UNICA should consider providing the following:

(a) information update

(b) locate institutions with similar programs

(c) obtain funds for holding symposia to allow for person-to-person technology transfer and to solve problems

(d) strengthen the technology in the area

(e) that contact persons become intimately involved in keeping their colleagues informed on technological development and funding availability in the respective fields of research

(f) for UNICA to improve the level of communication and information dissemination i.e., publication, with these contact persons so as to allow them to fulfill their functions. Some financial incentive for the additional work that the contact person will be required to do in the various countries ought to be examined.

A major function of UNICA should be the provision of funds. Unfortunately, its present structure does not allow for it to function as a funding agency. In recognizing the integral association between research and funds, we strongly recommend that UNICA consider approaching funding agencies such as FAO, CIDA, UNDP, UNESCO, CEST, OAS, OLADE, CDB, Ford Foundation, Kellog Foundation, etc. with the aim of discussing how UNICA can obtain funding for regional projects.

For short term funding in areas such as biogas which has wide regional applicability, it is suggested that since funds exist for environmental work, biogas projects be structured whenever possible to be equivalent to environmental protection projects and so become eligible for funding.

In our group we paid attention to three (3) basic questions which we felt were fundamental to the success of UNICA. These were:

(1) the ongoing R&D projects in energy within the region
(2) the requirements of our individual institutions from UNICA
(3) proposed methods which UNICA will employ to meet these needs.

In addressing the first question we realized that such information was extremely limited and the steps instituted by UNICA in the past by means of survey had not had the anticipated results. As a short term solution it was proposed that some time before the conclusion of this session all persons actively involved give a brief report on what they are pursuing and state whether they are interested in any form of collaboration.

The second requirement was for education. In institutions where technology is developed for the masses (e.g., charcoal project) in association with R&D we recommend that UNICA's know-how be provided to inform bureaucrats and potential users as to the need, as well as the operational techniques, for that technology. The social factors involved in giving new technology to our people cannot be overlooked.

In order to meet these needs we proposed that UNICA consider the establishment of a program for educating bureaucrats, and then an associated demonstration programme for the populous in the need and utilization of such technology.

Our second recommendation for UNICA, which is in the unique situation to identify and assess regional needs with regards to socio-economic parameters and then solicit the funds and award these on the basis of competitive grants for institutions or a combination of institutions to achieve these needs, is that such activities be done in

collaboration with other bodies in the region which share UNICA's concern for technological development in the region.

It is recommended that regional institutions submit collaboration projects through UNICA for funding. These two recommendations will allow UNICA to act as a stimulating and evaluating body to promote technological development within the region.

We all agree that the establishment of the Information Dissemination System is critical to the success of UNICA. This Information System is to be developed in collaboration with OLADE, TEU of CDB, CARIRI, SRC and other regional institutions. The prime purpose of this unit will be to acquire and disseminate information to UNICA contact persons in each country.

BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

San Juan, P.R., April 28-29, 1982

WORKSHOP SESSION, GROUP NO. 3

DEMONSTRATION NEEDS

Report by

Dr. Modesto Iriarte and Mr. Salvador Lugo
Moderators

General

This workshop was attended by a small group (six persons) representing Guyana, St. Lucia, Jamaica, Netherlands Antilles and Puerto Rico.

At the outset the group decided to establish the following criteria for the selection of demonstration projects: (1) availability of biomass on a commercial scale; (2) this biomass would be in an existing commercial activity; (3) the projects would be of such nature that they could be done elsewhere in the Caribbean (technology transfer); (4) projects should be culturally acceptable to the region and the countries involved.

With this criteria in mind, a discussion was held of the various biomass related activities being carried out in each of the regional areas mentioned. Various projects with a potential for developing into "demonstration" stage were discussed. Several were identified as needing further R&D, others were ruled out because enough commercialization has already been developed or because they were not within the general interest of the majority.

While sifting the options, the countries borne in mind in terms of biomass potential were Guyana, Jamaica, St. Vincent, Haiti,

Dominican Republic, Venezuela and Colombia. There could be others.

Only one demonstration project was identified and discussed at length for implementation. Discussions and reasons for discarding other projects are presented.

Demonstration Project for Implementation

It was the general consensus that a demonstration project to produce gas by pyrolysis of biomass would be very convenient for the Caribbean.

Gas is probably the best type of fuel for direct combustion; its transportation and handling and use offers advantages even over liquid fuels. The suggested project could start with a conference workshop sponsored by the University of Guyana and producing pyrolitic gas from the management of the forest industry. The gasifier has been developed by a German firm.

The conference at Guyana would include a series of lectures on the operational experience, and design details of the Guyana facility ecosystem impacts of the region as well as a visit to the plant. After the conference a task force would be identified to work in the development of this project. The task force could proceed as follows: (a) make an initial assessment of the process, the logistics and management, and outline a plan based on a selected site; (b) prepare a proposal for securing funding from private and government agencies; (c) implement the proposal when funding is secured.

Other Projects Discussed

(1) Direct burning of biomass was discussed. It was concluded that for small capacity boilers there is a long history of commercial

projects in operation. Demonstration needs are required for large utility boilers but the interest would be centered on a small number of the most developed countries such as Puerto Rico, using large blocks of electrical energy.

(2) Water hyacinths used for tertiary treatment as a source of biogas. This project was discussed and it was concluded that it is feasible but that there is not now too strong an incentive in developing a demonstration project.

(3) Sea weeds as a source of biomass. This was discarded because it requires R&D before a demonstration unit can be attempted.

(4) Need of data bank in biomass for the Caribbean. This was discussed and it was concluded that UNICA has a separate project on this.

(5) The need to determine:

(a) Bio-fuel consumption in the Caribbean
(b) Charcoal uses
(c) Fire wood uses

This can help in identifying further demonstration projects.

Other Recommendations

For consideration at some future effort for demonstration projects we wish to put forth the following possibilities: biogas or proteins from the banana operation at St. Lucia; explore in Antigua the possibility of biogas from the expansion of pork and poultry production. In Dominica explore possible use of wastes from coconut users and from food processing.

BIOMASS AN AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKHOP

San Juan, P.R., April 28-29, 1982

EVALUATION

At the close of the conference, an evaluation questionnaire was given each participant to elicit their reactions to this type of activity, and to obtain individual recommendations for improvement or modification of similar future conferences. A tabulation of the results of this evaluation follows:

TABULATION OF EVALUATION QUESTIONNAIRE OF UNICA WORKSHOP ON BIOMASS AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

	RATING							TOTALS	
	Excellent	%	Good	%	Fair	%	Poor	Resp.	%
Organization and logistics	4	31	6	46	3	23	0	13	100
Speakers	2	15	8	62	3	23	0	13	100
Workshop discussion	2	15	9	69	2	16	0	13	100
Overall	0	0	12	92	1	8	0	13	100

How successful was the workshop in meeting the UNICA project goals?	Very Successful	Successful	Somewhat Successful	Not Successful	Unaware of Project
	0	6	6	0	1

UNICA WORKSHOP ON BIOMASS
AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN – APRIL 28-29, 1982

WEDNESDAY, APRIL 28

8:00- 9:00	REGISTRATION
9:00- 9:30	Welcome – Dr. Juan A. Bonnet, Jr., Chairman UNICA Commission on Science and Technology
9:30-10:00	Introduction and the Role of UNICA – Dr. Thomas Mathews, UNICA
10:00-10:30	Coffee Break
10:30-11:00	Biomass Opportunities for the Caribbean – Mr. Lewis Smith, CEER
11:30-12:00	The Concept of Energy Integrated Farms – Dr. Jairo Lascarro UPR, Mayaguez
12:00- 1:00	Lunch (Speaker) Dr. Gerald Lalor University of the West Indies, Jamaica

WEDNESDAY, APRIL 28

1:00- 1:30	Closed Systems for Alcohol Fuels Production: Technological and Economic Evaluation – Dr. Michael Canoy College of the US Virgin Islands
1:30- 2:00	Anaerobic Digestion as a Source of Energy – Ladislaus Michael Szendrey Bacardi Corporation
2:00- 2:30	Anaerobic Waste Water Treatment – Eng. H. M. C. Kaspers University of Netherland Antilles
2:30- 3:00	Coffee Break
3:00- 3:30	Discussion
3:30- 4:00	Workshop Organization Dr. Howard Harrenstien University of Miami
4:00- 5:00	Workshop Discussion - Groups

THURSDAY, APRIL 29

8:30-10:00	Workshop Groups: Discussion and Drafting of Reports –
10:00-11:00	Coffee Break
10:30-12:00	Plenary Session: Presentation of Preliminary Workshop Results
12:00- 2:00	Lunch
2:00- 2:30	Workshop Groups: Discussion and Drafting of Reports –
2:30- 4:00	Coffee Break
4:00- 5:00	Plenary Session: Conclusion

WORKSHOP GROUPS

1. Research and Development Needs: Dr. Jose A. Lima, Facilitator
2. Demonstration Needs : Dr. Modesto Iriarte, Facilitator
3. Training Needs : Dr. Gerald Lalor, Facilitator

APDX