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

(Grant No. 1N'T-#025599)

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

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AND ENGINEERING IN THE CARIBBEAN

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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, from the workshops list of needs and priorities in  
education and training, research

on development, and demonstration

Projects that worked out are reported in Appendices D and E. Proceedings  
findings of both workshops are in preparation for publication.

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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 session 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 is 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 (CER) 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 completion of reports on the alternative energy data base and organization established. A proposal to fund the next phase, which includes

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.

Morrenstien, 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, » 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.

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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 technically suitable for the Caribbean, in rank order of estimated commercial readiness, is as follows:

Solar hot

Co-generat

Hydroelectric

im

2

8

4. Electricity from solid waste

5. Small wind awehines

6. Large wind machines

7. Blectricity from bagasse

Soler ponds

8. Photovoltetes

10, Ocean thermal energy conversion

11. Geothernal energy conversion

12. Other

Harrenstien (Appendix B) computed the value of contribution in Bois. of ofl saved per yeur for cach alternative energy technology at {the ?end of full commercinlization by the year 2000. This is presented in Table it, whore it can be observed that the combined contribution from the sources listed totats 154,250,000 Bbls. of cil saved por your, Consequently, the region could theoretically become energy self

Sufficient, as far as electrical generation is concerned, A plan of action or 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, Recognising 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, recruited from the universities and research institutes which are members of UNICA the pertinent official contact persons knowledgeable in energy. They will provide information on the energy state of affairs by their respective islands, participate in workshops, and serve as focus for initiating educational activities.

?) activities in their institutions.

Appendix C includes the names and addresses of UNICA Commissioners on Science and Technology and contact persons.

A questionnaire was circulated to all UNICA contact persons and the JOUGE EP members sent 100% maximum response. Only five of 18 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  
Latin American renewable energy matters in the Caribbean. After a search  
through general and specialized libraries and other information centers in the  
Caribbean, it was found that the best data were at the  
Inter-American Development Bank in Barbados, the Island Resources Foundation  
in the Caribbean and the Center for Energy and Environment  
Research in Puerto Rico. Table 111 summarizes the energy projects in  
the Caribbean region. Wind and biomass projects encompass the major  
activities 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 working  
shop in Barbados to the UNICA contact persons, who were re-  
quired to review it carefully and give their comments and suggestions,  
Only the representatives from Guyana, the Netherlands Antilles see the

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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 Summary

1. Wind as an Energy Alternative

for the Caribbean Worksho;  
oF the Caribbean Workshop

The first UNICA workshop was carried out in Bridgetown,  
Barbados on Docember 6-8, 1961. Some 50 persons participated. ?The  
workshop program is included in Appundix D.

The first part of the workshop consisted of background papers on  
wind energy. Especially significant was the participation of Dr. 1.8.  
Anderson, President of the USA Wind Energy Association, an organi,  
?on which has n Kees interest in the Caribbean. Following the general  
Presentations, the portieipants were divided in threc workshop groups  
covering the following subjects:

@) Eduction and Troining Needs

(2) Research and Development Needs

(8) Demonstration Noes

Each of the workshop session groups produced @ report which is

enclosed in Appendix D.

It is interesting to notice that the recommendations have similarities in that they focus on information needs and lack of human re-

Sources. A generalization and prioritization follows:

(2) A resource assessment of human and institutional capabi-

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ties, win 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.

Cher 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 L includes the evaluation of the workshop made by the participants.

Workshop on Biomass

Workshop 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 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.

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The biomass workshops indicated that the group feels that:

(a) Research, development and demonstration projects in bio-

mass energy source must be established in the Caribbean

region. Funding to carry out such projects is critically needed.

(©) Provision of training and education on Caribbean tropical

biomass is a must.

(8) UNICA should increase its information dissemination and technology transfer activities in the region.

(9) The role of the UNICA Foundation to secure funds to implement the recommendations of workshops is very important.

The Cat

Caribbean agricultural programs, especially in sugar cane and other food crops, are undergoing great economic stress. The possibility of 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 evotw

tion of this workshop indicated that it was even more  
successiul than the previous one. From the experience and recom  
mendations mace efter the first (wind) workshop, changes in onga-  
nization ond strategies were made. The evaluation is enclosed in  
Appendix Fe

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## CONCLUSION

It fs clear that the Caribbean region is richly endowed with  
Fenewsble alternative energy suources which could provide energy  
self-su?ficieney to the region in the decades ahead. Two of the main  
Sources--wind and biomass--have boen studied and analyzed. Curib-  
bean universities and research institutes should help in the devel~



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 have become aware of the region and willing to do something  
helpful based on solid ground. This effort is a very healthy seed,  
but we 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.

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CARIBBEAN DEMOGRAPHIC DATA

TABLE 1.







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LIST OF APPLNDICES

APPENDIX A

Bonnet, Juan A., Jr.. 1981: "Energy Alternatives for the  
Caribbean,? presented st the Workshop on Wind as an Energy  
AMternative for the Cariboean, 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 5, 1982.

## APPENDIX C

}. 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 Nuflez, 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 Luge,

Moderators

5. Evaluation

6. Workshop program

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APPENDIX &

# 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

ited 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.

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## OPPORTUNITIES FOR THE CARIBBEAN

By Dr. Juan A. Bonnet, Jr.

good news for the developing countries from Geneva at the  
October 1982. The Organization of Petroleum Exporting Countries  
(OPEC) decided to increase world oil prices to lead a cartel but we also  
decided to freeze this basic price until December 1982, thus protecting  
poorer countries from unexpected and unmanageable price increases,

unless long range steps are taken soon, the OPEC action may not be  
beneficial. About 100 developing countries depend on oil to meet more than 60

percent of their energy needs. Most of them import four-fifths of their  
oil requirements. The price of oil, in inflation-adjusted terms, has  
doubled over the past decade, and many analysts predict price increases  
of 10 percent annually. This means that the poorer countries now spend  
\$100 billion a year for imports of oil which could be paying \$110 billion a year by

119, Offset this economic drain, many countries are turning to the most  
world, available alternative supply. Forty percent of the developed  
world's timber reserves may literally go up in smoke as households end sea-  
sonally, Substitute firewood for oil. In a number of Caribbean countries  
exploitation of wood resources is not in equilibrium with regeneration rate  
Wood and charcoal meet a large part of Haiti's energy requirements and, there  
are a few, those of countries with forest reserves, such as "Beliz  
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  
fuel depends, in large measure, on the degree of flexibility they will

CINE t7 Managing their economies in the future.? Since the, Arab sil eobaree  
PE 2P74> the debt of developing countries has more than quadrupled-to e455  
Snare nGtUSiRg More of their income to? go for gebt service at continuoovsly  
increasing rates of interest.

he Morld Bank estimates that up to 30 percent of the developing world's  
Perey amgtGs Could be eliminated around 1980 by maximizing conservation ef>  
Coats GRd,by increasing eneray procuction from fuel sources such se oil) gees  
Coals hydropower and ?renewables. Tt nas outlined ways, of reducing these  
ESET fEGGS By 18 percent without secrificing economic growth during the  
coming decage,

Dering, 1961 there has been an increase of discussion ebgut energy.2 In  
poyenber 1981 south and north taiked about energy at the Canoe, Nerice Sumit  
see eee ya afore, this tn August there were discussions about renewable eneray  
AE Tie, Uptted Nations Conference on hw and Renewable Sources of tactay  
seironta? {For months there have been discussions about @ World Sank prosesal  
{0 fet up a Seperate eneroy affiliate within the Genk, but Up to now ne core

(On the other hand, according to the Interamerican Development Bank (1apB)  
Crude oi) production is growing faster in Latin America than in any other  
Tegjon of the world. In its 1980 report on economic and social progress in  
latin America, it stated that oi! ?production in Letin America. Cupanded. by



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By 2010, the region's share of the world market markedly rose from 9.6 percent in 1977 to 16.0 percent in 2000. In that year, the total output of the region reached 2.222 billion barrels (375,530,020 m<sup>3</sup>), compared with 1.111 billion barrels (177,765,010 m<sup>3</sup>) in 1977, an increase of 100 percent. The rate of growth in production has been 1.8 percent since 1973, and compares favorably with the 1.5 percent for the world as a whole. Combined production of Mexico and Venezuela accounted for 55 percent of the region's crude oil production from 1975 to 1990, although Venezuela's share fell from 83 percent in 1978 to 37 percent in 1990. Mexico's production rose from 18 percent of the region's output in 1975 to 27 percent in 1990. Concerning oil exports, "the single most significant trend during the past five years has been Mexico's contribution to the region's increased share of the external market," the TAGS report says. Mexico's exports increased 118 percent in 1990, 99 percent in 1989, and 55 percent in 1988 when they totaled over 30 billion barrels. Production also expanded in Argentina, Brazil, Peru, and Guatemala, but it declined in Bolivia, and Trinidad and Tobago. Production declines by almost 8 percent as a result of conservation measures enforced by the Government

the Mexican and Venezuelan governments are implementing an important of]

element? for the Caribbean. The New York Times

the Caribbean is being rediscovered again.? The

000 barrels for each country. According to the

it of the value of the crude purchased

by the recipient country will be financed by the ?Venezuela on the other hand

percang Central Bank of Hexico. The loan will be given for five years st aa

Peeseets Tate Of ,interest. If, nowever, noney is invested in develosment

End ene rabrererably in energy,? the loan? will be extended for twenty peers  
and the rate of interest will be lowered to 2 percents

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agreement covers up

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ane Horld Bank has also called for an internetsionsl research program to

ccaneriect Broaden the use of renewable energy technologies in Beveloping

sorakg Tes ple Bank, in @ recent report, ?Mobilizing Renewable Enevey voche  
pelegy in Oeveloping Countries: Strengthening Local Capabilities ed ker  
SSarchse Particularly emphasizes the role of biomass ?in the developieg  
Cones? Tenn ithoush in some countries up to \$0 percent of energy concumpeion  
Faprave om biomass. the report concludes that "present. research efforts te  
paproye Pionass. productiow ere inadecuate to begin to realize the crommore  
Posential of unis resource for the longer term. A well designed snd enced  
Rioness research program would improve the productivity of conventions! hee  
species thas. ars snes auRereane, cassava, and sweet. sorghum and identify  
Sbeeeegs that ere potentially wore productive. The research should be sare,  
counesieit, (O"eSETY and agricultural? Taborstories ?Tocated ?in, developing  
countries",

he second part of the World Bank proposal focuses on the development of  
fechmologies: for the production of energy fron direct solar, wind, seatt  
THLE iMG, Dionass ?resources. Gecuse a great deal of research to: improve  
Hiese technologies is already being dane in the developed and? in the nore  
Teeanegd \_seveloping countries, the program would ?be directed at ascistins  
THEE, evelopes countries: (LOCs) to ?assess and adapt new technologicve fee  
ERelZ, own national programs. The aim of such an international: program woutd  
be to develop reliable cata on ?renewable energy technolouy ?performace?

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uate enperiences in different countries » & adcpion of the tech.

nologies, end nske global assecsrents of fut cechmological developrents

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## EAN REGION

In the Carfbbeen region the crude petroleum and refined products share of tote] merchandise inports increesee from less then 9 percent in 19/1 to ebout. 2 percent in 1980. Petroleum imports to the Region increased during 1972-77 from \$180 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:

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

2) there ere no organizes 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 @ 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 IA

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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 electric

Electric 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. Countries are exploring the possibilities

of energy by the Region, and

highlighting non-conventional 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.

The Action Plan for the Caribbean Environment Programme calls for:

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

2) Management: will involve:

8) 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.

9) 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.

?) Development of @ 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 (CD3) and CARICOM, 28 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

---Page Break---

help Jamaica establish a» energy program. The goal of the

strengthen the island nation's ability to develop and carry out  
energy conservation programs and develop alternative

Notwithstanding these positive areas of interest and action on aspects of  
the Caribbean energy question, it may be observed that President Ronald  
Reagan's Caribbean Gas Initiative proposal did not make significant mention  
of alternatives even though Puerto Rico has proposed that the Center for Energy

Research of the University of Puerto Rico become the Research  
Center on Energy in the Caribbean, CEER's twenty five year  
effort of dealing with energy = the last five specifically on alterna  
tive and renewable energies = are a valuable platform from which many prob  
lems may be identified and solved. An encouraging sign may be recent  
indications of awareness that the CBI will make impact upon existing energy  
usage patterns within 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 Colombia basins and moves east relative to both the North American Plate on its northern edge, and the South

Atlantic Plate on the south (See Figures 2). The entire area appears to have been extensively intruded by large bodies of basaltic magma which developed deeper 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.

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).

Volcanoes exist in the Lesser Antilles. Martinique has the presently inactive Mont Pelee. In Guadeloupe a vein of steam connecting with La Soufriere volcano has been tapped by drilling at Gouvilance off the west coast. This drilling has been capped and, because the pressure is insufficient to overcome 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 Soufriere with 1 to 50 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 Geosynclinal 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

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Some traces of hydrogen sulfide are capable of polluting the atmosphere. However, this problem can be minimized with the appropriate use of resources. It is worth emphasizing that as of today, few serious studies have been made at the utilization of geothermal energy for power generation. Efforts have been made in the state of California, New Mexico and Nevada.

Among alternative sources of energy, solar energy has received the greatest attention. Essentially all our energy, except nuclear and geothermal, is derived directly or indirectly from the sun. The solar

pergation i the Cariobean Region is of the order of two thousand kilosuee  
Hours per, sduare acter per year. Average air teuperature varies from ohete  
Jerr ah February to ?3°F in Sepceiber. ?Rearly? fifteen ?tine sore eoaut  
EeGtation reaches the eerth's surfaces than the total consumption of comene  
TOMneray. Presently, solar energy is used on a very limited scale ie the  
Geriobean for crop drying, mater purivication, heating and Wistillation fs  
Se)ae aetilis have been buiTt by & fcreten research institutes: one do Haley  
ane one. jon St. Vincent tn the eastern Caribocan. ?These Stille have ova  
Hy provic te snail rural communities. Solar  
nutags in Grenada, chili peppers in  
The application of solar energy for  
qeeertitating Hes reached satisfactory levels of development in Jaraiee,  
Barbados enc Puerto Ricos

Survey undertaken in January 1982 by CEER, in conjunction with the  
Puerto Rico Department of Labor and Hunan Resources, Indicated that there  
mere ?approximately 18,000 residential hot water heaters in use, the devels  
PEEL OF Solar Industrial steam generators and solar air conditioner units

(self, being, pursued by the Center for Energy and Environment Research (SCEER) of the University of Puerto Rico. A 1,100 square meter solar water heating system installed in a renovated factory in Canovanas, Puerto Rico, and a new 400 square meter solar water heating system installed in a renovated Post Office in Guayama, Puerto Rico, are examples of commercial solar water heating systems. In Lagunas de San Juan, a 203-apartment condominium in San Juan, Puerto Rico, 3860 sq. 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 was completed for the Nestle-Libby food processing plant at Santa Isabel, P.R. The system has an active area of 50,400 sq. ft. Detailed system simulation studies predicted the solar array would provide 10°Etu/year to three distillation processes including pasteurization, sanitation and boiler preheat, thus representing an annual saving of approximately 102,000 gallons of #6 fossil oil,

A refrigerator designed to use hot water to reclaim refrigerant: the susto is



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echvelogy, have been built, sive promise of great. eure

?minicen Republic eng on the Carthhean island of Arguitla

ore oF Fetural salt-gradient pone: ere presently being cansie

iar energy? storages

a] Sarbecos sessive solar designs tave been used. An examble 1s the Teche

Fenn eeY, Unit Cau) suivaing: of the Caribbean? Gevelopment dani (COs

Specht BRIS ptseive syste tem prearess. hlsio e solar eft conditioning

si8lles and \$2 being tested in the new Barbados Goverment

and ?the vatin frericen Organtzstion. for steray

owing the design and fabrication of 8 seler syst

Vata total cost uf \$5.2 militun.

ie, largest solar hot water system in the Caribbean opened in September  
at the Cornwell Regional Hospital in San Juan. The project was sponsored  
by the Citizens Energy Corporation.

The Caribbean has almost everything in its favor to make solar industrial  
systems a success. It has an outstanding availability of direct, (comenenee  
Plentiful sunshine: an increasing well-documented insolation data base for  
the Caribbean @ the well-established tourist industry which reesies  
RETURNS and encourages the well-established petrochemical industry in such  
places as Trinidad, Curacao, the Virgin Islands and Puerto Rico. So one  
WANTS to try out @ new ideas, since they are either in the most favorable social  
and economic environment, or at the location where one has the greatest control over  
the operation. The fabrication of inexpensive collectors by unskilled labor  
is possible. Flat hot water heaters are already being fabricated in  
many of the islands. In Puerto Rico, a flexible glass solar concentrator collector  
for air conditioning systems has been developed and is being fabricated:

MLAS W VET personal belief that if industrial solar energy {s not  
SFuoR CaN viable in the Caribbean, 1t probably will not be vieble anywhere  
else in the worle,

### Ocean Thermal Energy Conversion (GTEC

As a potential source for comercial supplies of electrical eneray, ocean  
Spermal enersy conversion (OTEC) offers a viable answer. ?It could Sotome cee  
EA NOSE economical sources of ?energy yet conceived end is. sbundantly  
SHEE Te as, wotentian source ?of ?power for genereting electricity, any  
Eherme] (including guif currents) epgrey potential of the Caribbean \$6 estie  
ated at 182 billion Kwir per year.

Strong ocean surface currents pass through the Caribbean Sea from the  
Atlantic and continue with increasing speed through the Yucatan channel the  
Tei current flows at an average velocity of about one mile per hours Alece  
renpergture gradients between the ocean surfaces and 1000 meter ?depths are  
ore than 22°C (40°F). Great sources of untapped energy exist In these

GUTEMEE and temperature gradients. The maximum depth of the Caribbean? Ses  
45,0,180 meters about 160 Kilometer south of Puerto Rico in the trench  
Trough. However depths of 1000 meters are encountered two kilometers west  
of San Juan, Puerto Rico. CEER has been actively working on the development of an  
SHES, project on the southeast coast of Puerto Rico. Its floating platform  
Laboratory has run longer, continuously, than any other similar deep

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Shenandoah ML the most at probably the best site for this purpose in  
the United States, GEORGE is planning a "Gil" demonstration project in

addition With, the governments of Sweden, Norway and Finland although  
82 Established for the purpose. "The government of Holland has  
proposed a demonstration project for Curacao where @ depth OF 5.000 meters  
surface is located only 1,500 meters offshore. Guadeloupe and St. Martin have  
made preliminary evaluations of their OTEC potential and Barbados of the north  
on its east coast.

Hydropower is important in Dominica, Haiti and the Dominican Republic.  
Hydropower supplies 90 percent of power generation in Dominica and 27 percent in  
Suriname and Guyana. It could also play an important role in Jamaica  
and Barbados. In Guyana, hydro potential of from 71000 to 70000 hwh  
has been identified, and in Suriname a hydro potential of 10000 hwh  
exists. Belize is interested in mini hydro projects, and Colombia

is providing technical assistance to Haiti and Dominica to  
develop small-scale hydroelectric resources. In Colombia, the  
Ministry of Energy has developed some mini hydro technologies suitable for  
Biomass

Profoundly 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<sub>2</sub> and water into solid green water and oxygens

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, St. Kitts-Nevis, Anguilla, Trinidad and Tobago. Sugar factories in these areas generally satisfy all their energy requirements from bagasse and in Barbados, 20 percent of their energy requirements. Considerable use is made of bagasse as fuel for sawmills. In Guyana, Puerto Rico, and the Netherlands. Firewood, charcoal and bagasse provide an estimated 90 percent of all primary energy supplies in Haiti,

The energy content of dry bagasse is about 5.15 kilowatt hour per kilo-  
Bre: gn Extensive program of more than \$1.60 million for the development of  
re EEE O9G tropical grasses for energy use has been going on since 19)8 of  
the EER in cooperation with the Agricultural Experimental Station, In the  
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 run of  
TRUM" biomass (62 moisture) contains about 15 million BTU of energy  
This is the equivalent of two 42 gallon barrels of residual fuel oil. 4  
deed ye eg eaMt atoUnE of sugar and high test molasses are also? produced  
Guaged. It has been estimated by CEER scientists that 70,000 acres planted to  
energy cane would produce yields roughly doubling present sugar productions

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eliminate

molasses

rely Puerto Rican run industries: ?Uj dependence on imported

» Md reduce Puerto Rico's petroleum imports by 72.

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Studies currently suggest that costs would appr:

SE:10C per acre and yield Fiber and molasses produ

\$3,000 per acre, In spite of Inflation and Tish

Costs, It is possible that present, the plant energy cane i

Produce fuel at less than \$2.00 per million BTU.

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Positionwd to embark or 2 bi

iy typically Caribbean and

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port Tetitudc, its tropics! clinete cau sustain plant growth on @ yesr-round

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Gf Plank Species, both woody and herseceous that ere capeble of utilising

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fase fs humid", ine.) it receives abundant rainfall, while irrigation 1s

Nett Seveloped in the remsinine arid regions. There are six distinct ecolor

gical life zones. The lands themselves offer varied selection for both ree  
Sgarch and commercial development. Of Fusrto Rican sotis there are 9 Orders,  
27 Sgorders, 27 Great Grosps, 54 Families, ene 163 Series. It thus repre:

nearly BIT the Caribtzar in al) vts variety.

ioconverts fon

Biogas is produced when organic wastes, manure, vegetable matter or human  
waste are decomposed by bacteria in anaerobic conditions where  
those found in an airtight digester. The Biogas produced has a composition of  
approximately 58 to 65 percent methane (CH<sub>4</sub>) 35 to 45 percent carbon dioxide  
(CO<sub>2</sub>) and traces of oxygen, nitrogen and hydrogen sulphide. It has a calorific  
value of 11k with a calorific value of 20,000 to 26,000 Btu per cubic meter  
and can be used for cooking, heating and refrigeration. Once the gas produc-  
tion 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 ferti-  
lization.

412200 pig farm is being operated successfully by private enterprise in the south of Puerto Rico, AIT of the electricity at the farm comes from local biogas production, and also algae is grown as a feed supplement for the pigs,

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 2 biogas demonstration units. 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 herd of 400 registered Holsteins, to be increased to 500 head during 1982. The farm's 1982 average power demand will be about 1,680 kwh/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

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Plyfeee surstitutes: fron manure, cna (b) to establish a waste  
 System In conolience with Puerto Rice't environmental quality  
 she erevosed eneryy-integration corplex consists of eight Sub  
 These include corgonents tor ran rotion ang blending, @  
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 jing A foritoring subsystem 45 included. to ?assure ?comel sanee? woth  
 n From 30 to £0 percent of dairy feed requirements

1 ie provided by the integrated  
 Corporation has instelied 2 3.5  
 distillery residue

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Surping them in?

Disposal of municipal wastes becomes an increasingly serious problem

every year because of continuing urbanization of Caracas

Contamination of 2%; be possible for municipal waste to make a substantial

contribution to the city's air pollution and waste problems. by converting

solid waste into biogas for energy use. San Juan, the Capital of Puerto Rico

has been investigating the methane potential of its present landfill

iting

The northeasterly trade winds prevail over the Caribbean sea. The winds blow  
mostly from the east or northeast more than 70 percent of the time of  
the year, velocities of about 10 miles per hour. Because of this favorable  
condition, a wind power program was installed by the U.S. Dept. of  
Energy on the island of Culebra, Puerto Rico. This energy  
program, installed in 1976, produced 584,980 kWh of energy from 1976 to 1981, during  
which time the program improved blade performance and despite the occurrence of  
several hurricanes, the program is being continued. A salient finding here, however, is  
that the community in such projects. In Culebra, the community  
members favored wind energy as an alternative, their perception of the  
program'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 long periods. The use of wind energy for crushing sugarcane in small factories on elevated land in order to use the available wind for mills to crush the cane. This is true for Jamaica, Antigua, and other islands. In Antigua the Rockefeller Foundation has financed 16 turbines. Also 2 proposals for two pilot wind generators (56 and 100 kW) have been sent to the United Nations Interim Fund. The Caribbean Meteorological Institute is an active participant in collecting information about wind speeds in the Caribbean Region. A wind turbine has been installed in Puerto Rico by the Future Energy Resources Corporation.

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

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larger wind turbine generators is

effect, About 1 percent of the

exceeds the noise level

that trigger the noise

reduction. <sup>10</sup> Reducing

noise solves the problem, just? therefore be

concerned: of acceptable noise levels for these environments

Use computer programs to predict the

noise from wind turbine generators,

Future speed up.

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effects. The rotation of wind turbine blade

ency which may interfere with TV receptions

There are various solutions to this problem, depending upon the local

ice\_and reduction of wind power in nearby private properties

nce of wind turbine

Wing Tip Vortex is a phenomenon that occurs?

Recharge. At optimum operating condition of the turbine the effect

file as far as, the Cp of the machine rotor, causing &

. te the blades, For a 400%t. aver

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15 of wind turbine appear to be insignificant when

SEaRareS REE other? energy sources. Consequency, orgy than 100. United States electric utilities are considering wind projects.\*? Southern California Edison is already testing wind machines in the Son Gorgonio Pass and has signed agreements to purchase as much as 85 megawatts from 50 wind turbine farms. | Hawaii has signed a contract with Wind Farms, Inc. to install 20 SSE type turbines. on Oahu "by" 1035." Kina Forms, Inc. has persuaded Pacific Gas & Electric Co. to buy as much as 350 megawatts of wind power. sasnitree 2:5 Megawatt wind turbines (HC0-2) are generating at Goodnoe Hill, Heshington for the Bonneville Power Administration with turbine blades 400 feet long towers 200 feet tall; and the blades rotating at 17 rpm in Germany. Company MAN is engineering and constructing a Growian (grosse wind. energien Vege) 3 megawatt wind energy machine.

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 as the activity of man causes some kind of impact on the surroundings, the aim of 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 see this perspective as a resource potential to be harnessed based and, as such as biomass, and an ecologically friendly development approach for energy production including wind power is more suitable?

Coribacan renewable energies development and this are summarized in Table 2 It is important that these renewable energies be examined in other

by: Liquid transport fuels, biomass  
energy and These are outlined in  
mechanics and Applications\*, pre-  
4 and Renewable Sources of

technologies, mini-hydro, sea! Tescala

© end available for? rapid growth

tent & Forest of ?ene

United Nations

new and renewable. The three

sector and biowaste are electricity, forest

generation in 30 years. They can all be used in the Caribbean

Region. Table 4 presents demonstration projects in renewable

energy in the Caribbean Region. More details of some of these projects are

given in Energy Resources in Caribbean countries report. © Large scale

hydro, geothermal and, + ocean power will continue to play

an important role in the region which principally benefits urban

areas for various energy technologies such as the promotion

of energy efficiency and interest

in food production. Because of their

potential, the United Nations Energy Systems for

technologies for water pump

ation, ice temperature heating, cooking, crop drying, and power

generation are available and are expected to play a significant role in the near

future. Small end-use-size windmills used in decentralized mode are

becoming more cost-competitive in many areas, and medium and large windmills are

expected to be attractive enough for autonomous and integrated nodes of

power generation 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 and 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 the



in Puerto Rico transportation used up 2x 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 few "fixes" ~ engineering  
and administrative. Significantly, the report finds that in the area  
{transportation alternate fuels would create only a "fractional difference  
The more reason for increasing efforts to create alternate and renewable  
energies for essential needs.

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FIC I-A 1-8 ELECTRICITY CAPACITY AND PRODUCTION PER  
CAPITA IN SOME ISLANDS AND COUNTRIES IN THE  
CARIBBEAN

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## PLATE BOUNDARIES OF THE CARIBBEAN REGION

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APPENDL: &

ALTERNATIVE EXERGY IN THE CARIBBEAN

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Dr. Howard P. Harzenstien

ADSTRACT

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 renewable energy, under funding provided by the National Science Foundation, the Exxon Educational Foundation, the Caribbean Development

nt hank, and the Government of Venezuela, The project uses @  
fque hunt yesoures. tho mechenism of the network of the Asso-  
ciation of Caribbean Universities and Research Institutes (UNICA) to  
endorse a cooperative research effort aimed at increasing the  
Cy institutions to assist in the introduction of  
aternative energy solutions into the region. an element of data  
collection end systems unslyses 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 uscd 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 ali taking active roles in  
the assurance of the suececs of this activity.

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ALTERNATIVE ENERGY IN THE CARIBBEAN

Howard P. Barren:

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This paper reports on the progress of an ongoing project to

Develop the sensitivity of

d engineering capabilities of the universities

reh institutes in the Caribbean, in order that faculty,

student:

Stuff al these institutions muy assist in the orderly

developrent of

{grass-reots? conversion to

the vegion during the decades ahead. The project is funded primari-

ly by the Notional Science Foundation, under their Seienee in Devel

oping Countries program, and by the Exxon Eucational Foundation.

Additional invalvable ussistance kes been provided by the Caribbean

Bank (CDB), and by

ternative energy in

Develop

hc Venezuelan Government.

HH, BACKGROUND AN

D

Figure 1 sh

bean archipelago which have @ total land area of about 90,000 square

WS most of the 51 inhabited islands of the Cerib-

niles and # total population of approximately

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 {sland-communitios Gepend on imported fossil fuels for 99% of their energy 24)

?The Caribbean community includes the collection of geographical entities which occur in the vicinity of the Caribbean Sea. This sea is the port of the Atlantic Ocean lying dizectly enst of Central Ame-rica; north of Panama, Colombia, and Venezuela; west of the Lesser Antilles (Leeward and Windward Islands and others) and south of Cubs, Hispuniola and Pucrto Rico. The See is about 1500 miles long, 700 miles wide, and as deep as 22,788 feet. Ships which use the Pan ma Canal must by necessity pass through the Caribbean Sea, and ag a result pass close to many of the Caribbesn islands. Many of these

20 niltion. Only one of

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mn the

West Indies, which, according to Adolf A. Berle,  
former Assistant Secretary of State for Latin Amer

most strategically placed, everp



ulated, ethni

Aly complex and

pobtically divided archipelago on earth,"

1ee the 1650

the Caribbean has made strenuous efforts to  
by providing more jobs through industrilization  
ding tourism. As in so many developing countries

diversify its econ

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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 Cisnster area unless the dependence on imported fossil fuels is reduced and the use of elt

ive sources of energy is greatly

Diocks 10 progress ure (n) lack

npower, (b) inadequate research f

nology and udups

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Four of the major

the use of existing tech

tion or modification of the various technologies to  
nment, (e) the lack of a grass roots  
cooperative .energy program involving the universities and research  
institutes of the region, and (é) the lack of investment capital

sical en}

A system of cooperation is of great importance in a region  
Whose history has been one of

?agmentation and of dependence on  
external markets and external authority. The project must provide  
for, and depend upon, the active cooperation of universities and  
Fesearch institutes from the Spanish-speaking, English-speaking,  
French-speaking and Dutch-speaking Caribbean. The levels of  
research work will vary, and this requires advenced 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 @ bitter legacy of resent-

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even of hatred. The idea

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Such conflicts are

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evidence of is, just us the bout-people from Cubn and Malti and

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?ution into Puerte Rico from the Domini

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ortant, bur it cannot of itself provide w

Gientors of u growing poverty and ciseonter

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in the Inst resort, on the

people to analyze their problems and,

with as,

to find solutions for them. Cooperative

relationships between indivieal United States and Caribbean univer

sities, though v in themselves, do not fully meet the need for

© Gonor-recipient relationships into # large partnership of

and scientists. This is why the project attempts to make  
network of Caribbean institutions, providing a

appropriate centers within the

region, and

wants to fund research programs and in the prepara-

tive regional program for using alternative

sources of energy. Through these 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 inexhaus-

ible alternative energy sources. In addition to geothermal energy,

which is in abundance in locations such as St. Lucia, many feasible

inexhaustible

P-related alternative energy sources exist. This is largely due to the fact that the Caribbean, within a latitudinal range of 10°N to 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.

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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 uni-

versities and research institutes:  $\phi$

play in meeting that need; and

on the fact that the region has a rich potential in inexhaustible

's. 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

cept of the region as a laboratory for the development of alternative

in which lessons can be learned and demonstr

Mons carried out that will be of benefit to other countries that have

y to an exciting con

sources of energy

Because of the urgency of the energy situation in the Carb

been, it is crucially 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,

0 the ord

II, URICA 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 Harrenst4en,

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.

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In the Inte IAs, pe

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men regional concern. To meet their common needs they ercated

UNICA, a voluntary associetion of Curibbean universities and

Research institutes dedicated to positive carefully-directed efforts for Caribbean development. Founded in 1966 by 16 universities located in ten Caribbean countries, the organization now has 43 members representing constituency of more than 300,000 students and 39,000 faculty.

In order to lend assistance and impetus to the goals of UNICA, Union of Caribbean Universities and Research Institutes Inc, was created. With Dr, Henry King Stanford, re  
Univer

y of Miami, as President, the Foun-

n-profit organisation in Florida. It

?tox exempt status as a public charity by the

Antersul Revenue Service and support to the Foundation is tax

Geductible 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

?agreed to support this project.

Cation was established es 2

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## SOURCES ASSESSMENT

Demographic and statistical data for most of the island communities involved in the Caribbean region are contained in Table 1.

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

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in nature, and must not be overestimated as to its accuracy, as its purpose is only to allow preliminary assessments to be made. Never-

theless, it is hoped that these data will be 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 in the future, as

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Table 1 estimated 2 total population among all of the istands mentioned of 15,196,800. This figure {s 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, und the estimate of combined projected shoreline which is normal to the prevailing trade winds is &: ?at 87,950,000BBLS of oil per year are imported by these islends collectively to provide electrical influence of Puerto Rico is



miles. It is estimated

energy to their population, If the

subtracted from these totals, they become 14,861,800 persons,  
26,778 square miles, 787 miles, and 16,078,000 BBLs 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 tech-  
nologies which were deemed technologically suitable for development in  
Puerto Rico 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:

Solar Hot Water

2. Co-generation

Hydroelectric

Electricity from Solid

Small Wind Machines

---Page Break---

Large Wind Much

6 wee Cvinefarms)

7. Tieetrietty from Bagasse

8, Llectricity from Solar Ponds

9. Photovettuies

### 30. Ocean Thermal Ene

### 21. Geothermal Energy Convers

### 32. Other

A preliminary estimate of the potential of these technologies as  
fer es replacement of imported fossil fuels is concerned may be pro-  
duced by assuming that the islands in the Caribbean have many simi-  
lrities of character, and that lifestyles will eventually reach similar  
levels of industvialization and Gevelopment. One ean then take the  
current estimates of potential for Puerto Rico und use them in pre-  
dicting the potentiad for the remaining islands in the Caribbean.

Table 2 computes the valves 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 154,230,000 BBLs 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, subtracting the contribution from Puerto Rico, the region imports only 16,078,000 BBLs 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 42,662,374 BBLs of oil per year. Energy self-sufficiency, then, as far as electrical generation is concerned, is achievable by the year 2000, if the case:

utilizes 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,

regional commercial

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This is very good news for this region, but » plan for orderly development und 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 ps

ing for further

esetlating imported oi) 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 mejor contributions in the immediate future. These are Wind (Numbers 5 and 6) and Biomass (Number 7), In recognition of this potential, the UNICA Commission fon Science and Technology selected these for eerly emphasis. A Progress report on the result of this activity is contained in the

following section.

T

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 alternati

es 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 6-8, 1981. A workshop was presented at that time titled "Wind

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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

Moderator

» Training - Dr. Howard Harrenstien,

+ Research and Development ~ Dr. Edwin Nuflez, 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 pat

opening in communication links on wind energy in the Cai

Miclpants, and from the point of view of providing an

bean

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 @ 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.

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3. Source

of funding should be identified which will enable the continuation of the program which was initiated by this conference and which will ensure the timely completion of priorities  
Land 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

i be greatly

enhanced and strengthened, us for as this form of alternative energy

Js concerned.

The draft of the proceedings of the Barbados Wind Workshop

has been prepared, and copies may be obtained by writing:

b:

Asociación de Universidades e Institutos del Caribe

Apartado Postal 11532

Coparra Heights Station

San Juan, Puerto Rico 00922

?Thomas

thews, Secretario General

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, 1952. 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.

## VII SUMMARY

Energy consumption patterns for the Caribbean and alternative energy 93

assessments and analyses are continuing activity by the Research staff. Results of some of the early assessments were compiled 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 head. Whether they do or whether they don't is @ 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

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APPENDIX ©

MEMBERS OF UNICA SCIENCE AND TECHNOLOGY ComaiSSION

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## CE AND TECHNOLOGY COMMISSION CONTACT PERSONS

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APDX. ?

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APPENDIX D

Report on

Wind as an Energy Alternative for the Caribbean Workshop

Barbados, December 6-9, 1981

UNICA Commission on Science and Technology

---Page Break---

APDX. D-1

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 evaluation by the participants, and from the point  
of view of providing an open

f in communication ?inks on wind

chery in the Caribhesn scientific and engineering eaucational and research community.

Although the three cuiminsting workshops were conducted inde-  
Pencently from one another, recommendations produced by them had  
Some marked similerities and focus. All three reports are included  
hem, A eneralization o\* the recommendations and « prioritization  
results in the following conceptual overall recommendetions.

4. A resource assessment should be conducted to determine  
the existing situation in education and training,menpower, the  
magnitude of the available wind resource, the availability of  
#ppropriate wind sites, and the existence of wind demonstration  
projects in the region.

2. Besed on the results of the current "stete of the art?  
sesessment in priority £1, @ plan should be prepared which  
Would deteil the steps (including costs) necessary to accomplish  
oF acceptable level of progress toward achievement of the rest  
of the recommendations from the individual workshops.

3, Sourees of funding should be identified by the UICA  
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.

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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.

UNICA Science and Technology Commission stands ready to assist on a mechanism through which the above may be accomplished,

and by which UNICA member institutions may better service the com

munities in which they are vented 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 Foundation, the UNICA Foundation, the Caribbean Bank and the UNICA staff.

Development

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APDX. 0-2

AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP

Barbados, December 6-8, 1981

WORKSHOP SESSION, GROUP NO. 1

EDVCATION AND TRAINING NEEDS

Report by:

+ Howare Horrenstien, Moderator

is workshop session was u'tended by 15 persons representing  
nine countries:

3. Quilvie Cabrat Dominican Kepublie

2, Ronin \$. Cristébal Dominic

3. Homes Poot Dominican Republi

4. Miche) DuPont Guadeloupe

5. dessel Edwards Antigua

©. Hopeton Gordon Guyana

7. Fowsrd Harzenstion Florida, USA

Rivet Hughes Anguilla

8. Pobert J. Martin Puerto Rico

16, Paul Neua Barbados

1. Rerate Biter Dominican Republic

12, José B. Rodrigue Dominican Kepublie

13, 8. Sateunanathon Trinidad

MM. Muelano Sbriz Dominican Republic

15, Robert Sullivan Florida, USA

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

---Page Break---

(G2) What has been done in wind energy education and training in the Caribbean?

(2) What should be done sn wind energy education end training

in the CaribLean 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 needs for the future, a poll was conducted of the participants to determine their assessment of these conditions. The results of the HI 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 1.8 which is between "moderately active" for the desired future state.

tely" in

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 petition.

headings of Table 1, These categories are the following:

(2) Engineering education programs at the baccalaureate Level

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

(2) 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.

(8) Modification of high school and university curriculum to place increasing emphasis on alternative energy related subjects,

---Page Break---

(@) 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:

(2) 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 netud in recommendation #1 to meet the requirements outlined in recommendation #2.

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

(8) \_UNICA should sponsor regular meetings whereby university feculty, researchers, and education snd training specialists can essess the status of completing recommendations #

4,

(6) Libero! use of the following mechanisms should be usec to accomplish the necessary educational and training mission:

---Page Break---

Short courses:



Institutes

Fellowship program

Correspondence courses

Curricular development packages

Post-doctoral programs

Sabb:

Is

Symposia and conferences

Faculty and researcher exchanges

Videotapes of demonstrations and applications

PF

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

ond equipment, and the

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 -- NGftez, Roman, Rodriguez, DePool, Sbriz

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

(2) 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.

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

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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 14 seminars to their members in which are

Presented actual problems relating to energy problem,

(a) Institute

See the financing of housing to offer

incentives 10 clients to use solar heaters instead of electric

What should we do in addition?

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

(&) Suggest to these same systems to introduce « mandatory course on problems relating to energy in all of their Professional programs in technical areas end at the same {ine taking into consideration energy problems in the courses of the programs which in one way or another treat these same problems.

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

(4) 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,

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@)

(©) 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 education

educating students at this level on this matter.

campaigns in the secondary schools

(g) Consider the possibility to rural areas to install windmills

for their use in obtaining the necessary water for their

communities

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 ins-  
titutions 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 re-  
sources. However, their influence on government officials  
is not enough and their available means to bring to ful-

Elementary 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.

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WIND AS AN ENERGY ALTERNATIVE FCR THE CARIBBEAN WORKSHOP

Larbades, December 6-8, 1981

WORKSHCP SESSION,

GROUT NO.

RESEAPCE AND DEVSLOPMENT NPLDS

Report by

Br. Puwin Nufez, Moderstor

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

Fein Nitier Puerto Rico

i Melvin Sanktos Guyane

b. Sixte Wout Curneve

fe Stephen Lamuing Barbados

Lester Neleor Crenade

Soseph Lanicl Montserrat

Michsel Canoy U.S. Virgin Istanes

8. Richard L. Simon California, USA

9. José B. Rodriguez Dominican Kepublic

10, Majeraj 8. Toniar Venezuela

1, Devid 8. Renne Washington, USA



# 1, 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 the maximum number of its citizens a high standard of

---Page Break---

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 energy research and development policies.

It is the belief of the participants of the research and development needs workshops that the advantages of « 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.

MU, 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, RED is much harder to undertake in these countries than in industrialized nations.

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Workshop participants agreed on the following list as the most important impediments to their RED efforts.

2) 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 with other specialists in his field. Libraries lack the most current journals or books.

(2) Lack of infrastructure - ?The infrastructures we see

sur (6 deploy, upernte ord ma

bain & new technology are

venitly noneaistent.

(8) Overinvolvement = Being one of the very few tech  
Highly 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

solver. 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 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 - 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

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m,

Proper participation of scientists and engineers. Funds are allocated by people who lack a real understanding of Rap.

## RESEARCH AND DEVELOPMENT

EDS

Wine 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,

(2) 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

ascertain the best locations to install both large and small scale wind turbines,

(3) Evaluation of existing

of adapt

ing technology and the development

of solutions 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,

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#### IV, RECOMMENDATIONS

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

2) Top priority should be given to wind resource assess~



Ment proprens ond wind siting studies, Within @ period of  
?our years. all Cribben islands should know their colic

(2) Projects aré studies should he funded which consider  
the economic, social und legal impact of alternative energy

systems. in pwtievlar wind turbines.

(8) It iy deemed important te sponsor projects which use  
fan integrated systems of energy approach sveh as soler/  
biomes, wind/hydro, wind/sclar, etc. The domestic, in-  
Gustrfal ané agricultural applications suiteé to the par-  
ticular country's milfeu should be explored

(4) Research in the problems assoclsted with the opera-  
tions an? maintenance of alternative energy systems should  
be undertaken. Speciat attention should be given to the  
Problenss associnted with materinls and parts resistance to

salt corrosion and protection from hurricane force winds.

(5) Tecal 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

---Page Break---

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

(Priority should be granted to projects which explore the energy production and utilization systems. Energy conservation and second: potential of solar

efficiency projects offer the

ing vast amounts of energy in the region.

(©) A survey should be conducted of the available human resources in the region with expertise in the energy RD areas. After the survey is conducted @ human resources and project @irectory should be published and an institution of 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.

(8) 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.

(20) 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~

---Page Break---

Ppective participants can decide wisely on that basis  
whethi

to attend or not.

QD 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 « wind turbine,

( ) allowing the individual consumer to sell energy

Produced by « wind turbine to the power company

(similar to PURPA in the United States).

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

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## TABLE 1

Advantages and Disadvantages resulting from Caribbean countries

elaborating and implementing their energy research and development policies

separately or unified.

Advantages

Separate (each

?country having

an ?dividual

approach)

Country can pinpoint

YES own RED needs very

precisely and work on

Country can proceed at  
its own pace without  
being bound by others

United (groups  
of countries  
working together)

Cost savings. Pooling  
Of resources will mean  
lower planning, equip-  
ment and data analysis  
costs

Countries can complement  
each others necessities  
by Sharing their human

and technical resources

Region-wide spirit of  
cooperation

Possibility of pooling  
together to purchasing  
alternative energy  
systems (wind turbines,  
Sigestors, etc.) at a  
reduced price

Disadvantages

Higher cost to each  
individual country

Lack of technical  
and human resources  
will probably require

Resource intensive fore-



ign (outside of Carib-  
bean) participants

Potential political  
problems,

Delays in getting  
done due to the neces-  
sity of allocating Timit-  
ed resources to various  
countries,

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APDXx. D-4

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

WORKSHOP SESSION, GROUP NO, 3

## STRATEGIC NEEDS

Report by

Dr. Modesto Iniprte, Moderator

workshop was attended by eight persons

representing six

Cristobal Román & Dominican Republic

Inés Sbrte Lominiean Republic

sin, Sparks. St. Lucie

5 Creer Guarda Nexieo

S. Peter Willems Barbados

+S. Anwutsont usa

3. Dellimore Barbados

8. Modesto Inurte Puerto Rico

It was found that each country has different demonstration  
Project 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 com-  
munity needs, the needs of electric power for solving critical needs

---Page Break---

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 vio-  
lating social laws. This represents an obstacle to WTG development,

The group generally concurred that wind power assessment pro-  
cesses in the various ercss 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 commences that an inventory of existing demonstration. pro-

jects be first made, The purpose of this inventory  
completion are

(1) to prevent duplication of efforts.

(2) to provide assistance 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.

(8) 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?

---Page Break---

Purpose of unit:

(@) water pumping

(&) electricity. production

(©) mechanical

(a) other

Designer of unit:

(a) manufacturer of unit

(©) designer (if unit locally built)

(©) level of local component in design and manufacture of unit

If locally built, are plans or report available?

Funding Agency:

(©) privately owned

(b) government funded

(©) funded by outside source

() other

Is wind data available?

(2) at site location

() at other locations

Condition of unit

() under construction

(>) working

(c) needs repair

(2) planning stages

If working, performance of unit:

(@) details

---Page Break---

If needing repair:

(a) advantages to repair

(>) estimation of cost

(e) details

If in planning, has funding been acquired?

Identify type of future demonstration projects needed in the

(03. estimation of cost

( ) planning requirements

(c) possible funding agencies

(2) specific help you would like to secure

A set of short term objectives (say for 6 months accomplish

months) was outlined by the group participants as follows:

(1) Catalog existing wind turbine installations.

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



(©) Removal of obstacles to wind turbine development;

legal problems in different areas.

study

(@)\_ Rate structure consideration from wind sources.

(S) Identify incentives to promote wind turbine development.

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

---Page Break---

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

preparing the questionnaire

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

this symposium

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

GH vavel to these en

8 in arrears in returning the information questionnaires,

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 be the contact man in each of the areas from whom he will obtain the information.

?The inform

follow up or update

va will be gathered, reduced, and published. A

© wetion every year should be attempted.

fits

This information would provide e data base for the various countries to reduce duplication fferts, to be in # better position to Present proposuls for requesting funds for their projects. Other ospects in which this ectivity could help would be in accelerating the evelopment and use of wind power, the pricing and costing of

Power produced, determining appropriate sale back prices of electricity to local utilities, etc,

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?This information would identify the difficulties and failures of the existing demonstration projects und provide guidance in instra-menting procedures for dccumenting and reporting the operation of demonstrasion projects.

## Funding

The group's opinion is that funding should be addressed jointly from the identified needs of the three workshop groups. However, for 1 job should be assigned of about 5 man-years for the project coordinator plus travel

When budgeting it can be estimated that

expenses, plus 5 man-years secretarial services in addition to over-

head costs of office, telephone, reproduction, etc.

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

---Page Break---

APDX. D-5

## 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 (778) gave "Good" (one step below the maximum "Excellent") to the Workshop. It is also worth noting that the group discussion format received the highest percentage (55.26) of "Excellent", while the question on speakers got the lowest "Excellent" percentage (03.86). Another interesting finding is that 17.28 of respondents indicated that they were unaware of the UNICA Project goals.

an overall rating of \*

?These on cther observations, criticisms and suggestions will be  
laken ito consideaution in the organization of future workshops, in  
particular the biomass workshop scheduled for the spring of 1982 in  
Sen Juon, Puerto Rico under the UNICA Project.

---Page Break---

WIND AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN WORKSHOP  
EVALUATION

Question Number Percent.

1. Organization and Logistics

8 27.8%

? 58.6x

4 13.8%

0 °

Excelent 4

Good at

Fair 4

Poor 0

3. Workshop Ofscussion

Excellent 16 55.2%

Good 4 13.3%

Fair 0 0%

Poor 0 0%

4. Overall

Excellent 6.5 22.44%

Good 22 15.44%

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 15 39.72%

Somewhat successful 31 51.1%

Not successful 1 3.48%

Unaware of the UNICA Project's goals 5 12.5%

Other: answers 1 3.8%



No answers L Ban

TOTAL RESPONDENTS: 29

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APPENDIX E

Report on

Workshop on Energy Alternative for the Caribbean

Workshop

San Juan, Puerto Rico

April 28-29, 1982

UNICA Commission on Science and Technology

---Page Break---

APDX. E-1

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 with 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» HM Seminar which provided the UNICA contact persons a unique opportunity to become acquainted with the subject.

Again, following the format of the Wind Workshop, the group was separated into 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 for tropical biomass for the region are a must.

---Page Break---

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

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

such programs,

IF the above recon

foundations are implemented the science and engineering capabilities of UNICA member institutions in biomass betters would be greatly enhanced. Also, the role of the universities and research institutes as providers of solutions to society should be strengthened

UNICA Science and Technology Commission wishes to thank all the UNICA contact persons for their participation in their workshop 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.

---Page Break---

APDX, E-2

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

Pr. R.L, Sullivan, Moderator

participants in the Education and Training Workshop session

include:



Pr. Jaime Suscarre (University of Puerto Rico)

Eng. Gerardo Manan Paniegva (INTEC, Dominican Republic)

- Lourdes Iturrolde (Universidad Simón Bolívar, Venezuela)

Sir. William Chalmers (Caribbean Development Bank, Barbados)

Dr. J. O'Brien (University of the West Indies, Jamaica)

Mr. Gerald Leler (University of the West Indies, Jamaica)

Dr. T. J. Sullivan (University of Florida, USA)

Recommendations

(G2) 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.

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

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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 procedure.

(5) UNICA should tune 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 technologies.

(2) Boeh was

the state of

and, group should

publish an edited volume describing

the content of its specific technology for each country

in the region

(8) The working group should be responsible for promoting its

specific areas 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.

---Page Break---

APDX. E-3

BIOMASS AS AN ENERGY ALTERNATIVE  
FOR THE CARILBEAN 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  
treat Led 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 slow 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:

(2) Inequalities 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

ment

?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.

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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

technologies 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 needs in the region,

A technical-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 financial applicability and potential. That U.S. AID policies in the region should be evaluated to see how they promote:

(a) regional collaboration

(0) developing expertise within the region

---Page Break---

?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 development 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. Kencux 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

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 allow UNICA contact persons to be aware of funding availability for research and distribute this information to people whom they think can benefit from this.

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---Page Break---

TUNICA should consider providing the following:

(2) 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

(6). strengthen the technology in the area

(2 that contact persons become intimately i

volved in keeping

their colleagues informed on technological development and

funding availability in the respective fields of research

(OD for t

uation 6

ICA to improve the level of communication and infor

mination i,

++ publies

jon, with these contact per

sons \$0 us to ther to fulfill their funetions, 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, CES, OAS, CLADE, CDE, Foré Foundation, Kellogg Foun-  
dation, 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 environmental work, biogas p

that funds exist for

festivals be structured whenever possible

to be equivalent to environmental protection projects and so become

eligible for funding.

---Page Break---

In our group we paid attention to three (3) basic questions

which we felt were fundamental to the success of UNICA. The

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

M1 addressing the Srst\_qu

motion was extremely limited due to the st

question we realized that such infor-

tuted by UNICA in

3 hours! we had the anticipated result

suggested that some time before the

conclusion of this session all persons: actively involved give a brief

report on what they are

interested fr

discussing and state whether they are inter

Wy form oF co

The second requirement is for education. In institutions where technology is developed for the masses (e.g, charcoal production) UNICA'S know-how

is not sufficient. Users as to the operations! techniques, for that technology.

The social factors involved in giving new technology to our people cannot be overlooked.

fact) ix: association with KAD we

Med to inform. bare:

need, as well

In order to meet these needs we proposed that UNICA consider



the establishment of a program: for educating bureaucrats, and then  
an associated demonstration program for the population in the need  
and utilization of such technology

Our second recommendation

is for UNICA, which is in the unique  
situation to identify and assess regional needs with regards to  
socioeconomic parameters and then solicit the Surveys upward these

on the basis of competitive grants or incentives combination of

institutions to achieve these needs, is that even activities be done in

---Page Break---

collaboration with other bodies in the region which share UNICA's

concern for technological development in the region.

It is recommended that regions/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 Dis-  
tribution System, is critical to the success of UNICA. This  
Information System is to be developed in collaboration with OLADE,  
TEU of Gb, CALIR, SRC and other regions!

stitutions, The  
prime purpose of this unit will be to acquire and disseminate  
information to

MICA contact persons in each country,

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APDX, E~@

BIOMASS AS AN ENERGY ALTERNATIVE  
FOR THE CARIBBEAN WORKSHOP

San Juan, PR, April 28-20, 1989

WORKSHOP SESSION, GROUP NO. 3

DEMONSTRATION NEEDS

Report by

Dr. Modesto Bnarte and Dr. Salvador Lugo

Moderators:

Genera

this work rep was attended by a small group (six persons) re=

Presenting Guyana, St. Lucia, Jamaica, Netherlands Antilles and

Peerto kico.

#t the ontect the group decided to establish the following eri  
terlo for the selection of cemonstration projects: (1) availability of  
Biomass on & commereiel scale; (2) this biomass would be in an  
existing commercial activity; (3) the projects would be of such  
ature that they could be done elsewhere in the Caribbean (tech=  
nology trensfer); (4) projects should be culturally seceptable to the  
Fegion und the countries involved.

ith thie criteria in mind, a discussion was held of the various

Biomass related activities being curried out in each of the regional

areas mentioned. Various projects with » potential for developing

into "demonstration" stage were discussed. Several were identified

needing further RAD, others were ruled out because enough com-

mercialization has already been developed or because they were not  
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,

---Page Break---

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,

the General consensus that © Demonstration project to

BRMECE E88 By vryelysin of Blomeas would be very convenient for  
the Caribbean,

2s ts prot

'y the best type of fuel for direct combustion; its

Erstertation cic bonding aré use offers advantages even over  
ule fuels, The suggested project could start with a conference  
workshop sponsored by the University of Guyana and producing:  
Porelive gas (oon, the managersont of the forest industry. ?The  
Gusifier has beer. Developed by a German firm

This conference at Guyana would include a series of lectures on  
the operations! experience, and design details of the Guyana facility  
Gcesystem, impacts of the region as well as a visit to the plant,  
After the conference @ task force would be identified to work in the  
Gireleprent of this project. The task force could proceed ee  
{cliews: (@) make an initial assessment of the process, the logistlog

\ arageneit, re outline 6 plan based on a selected sites

@) Prepare 1 proposal for securing funding from private and  
Government agencies; (6) implement the proposal when funding is

#### Other Projects Discussed

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

---Page Break---

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  
Docks of electrical energy

(2) water yzclnths used for tertiary treatment as a source of bio~  
Bes. This project was discussed and it was concluded that it is  
feasible but that there is not now too strong an incentive in  
Developing & demonstration project.

(3) "Ses weees 48 a source Of biomass. ?This was ésearded because  
H woutres Kul) before a demonstration unit can be attempted,

(2) Need of

\* bank in biomass for the Caribe  
cussed and It was cone  
this.

This was dis  
fused that UNICA hes @ separate project on

(8) The need to determine:



(3) Lie-fuct consumption in the Caribbean

() Cherooul uses

(©) Fire wood uses

?This can help in identifying further demonstration projects,

Other Recommendations

For consicevution at some future effort for demonstration pro-

Jeots we wish to put forth the following possibilities: biogas. or

Proteins from the banana operation at St. Lucia; explore in Antigua

{he 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.

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APDX. B-5,

BIOMASS AN AN ENERGY ALTERNATIVE

FOR THE CARIBBEAN WORKEGP

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

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  
(OIL BLOOM AS AN ENERGY ALTERNATIVE FOR THE CARIBBEAN

TOTALS

EiceTTent Goode Tatr ?¥ Poor Resp

Organization and

logistics 4 on 6 6 3 2 ° 13° 100

Speakers. 2 1 8 6 3 a o 13, 100

Workshop

discussion 2 1 9 9 2 6 o 13° 100

Overall o ow 2 1 8 ° 13 100

How successful Very Somewhat Not Unaware

was the workshop Successful Successful Successful Successful of Project

in meting the

UNICA project

goats? ° 6 6 9 1

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