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DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE
AND ENGINEERING IN THE CARIBBEAN

(SF Grant No. 1Nt-?302757

FINAL REPORT

Submitted to

NATIONAL SCIENCE FOUNDATION

by

Juan A, Bonnet, dr,

Principal Investigator and Chairman

UNICA Science and Technology Coanission

Decenber 22, 1963,

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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Bonnet, Juan A.» Jr.y and Wallace C. Koehler, "Develop-

iment of Alternative Science and Engineering inthe Carib-
bean."

Farber, Erich A., "Solar Energy Conversion, Research and
Development at the University of Florida.?"

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DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE
AND ENGINEERING IN THE CARIBBEAN

NSF GRANT NO. INT-8302757

FINAL REPORT TO NSF

1. EXECUTIV

summary

This was the third phase of a project whose primary objective is to develop the scientific and engineering capabilities of the universities and research institutes of the Caribbean and thereby to assist in the introduction of alternative energy solutions into the region. The project was conceived by the Science and Technology Commission of the Association of Caribbean Universities and Research Institutes (UNICA) and carried out under the leadership of the Center for Energy and Environment Research of the University of Puerto Rico. The financial support of the National Science Foundation greatly facilitated the accomplishment of the project's objective.

This part of the project consisted in a four-day Solar Energy

Utilization Workshop for the Caribbean Basin held at the University of Florida in Gainesville. The workshop was carried out by personnel from the Solar Energy and Energy Conversion Laboratory, and the International Training Center for the Training in Alternative Energy Program. It included the basics of solar energy conversion and utilization with presentations on specific problems found in the Caribbean Basin. It also included site visits to review solar hardware development and demonstration projects in the Gainesville area. All the major lectures were videotaped.

A discussion workshop was held on the last day to develop specific organizational and research plans that will permit UNICA to strengthen its institutional capabilities to facilitate the search for solutions to the pressing energy problems of the Caribbean Basin. Based on the cumulative experience of this workshop and the two previous ones on wind

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energy in Barbados, December 1981, and on biomass energy in Puerto Rico in April 1982--a detailed proposal to implement cooperative projects is being prepared to be submitted to international funding institutions. The overall plan proposes, among other things, the compilation of a directory of Caribbean human and institutional capabilities and the creation of a Caribbean research endowment fund. In the education and training areas it provides for technical curriculum review, an energy

auditors training program, @ Caribbean universities information network and speakers bureau, and faculty enrichment through interchange programs. It also contemplates solar hardware information dissemination, technology transfer activities, improvement of solar systems maintenance, solar wind measuring equipment utilization, and video facilities.

The prioritization of this agenda resulted from discussions and interchanges with the end users, the UNICA contact persons. That in itself is one of the major accomplishments of this project.

The ensuing report summarizes the project's main activities and accomplishments.

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General

?The universities and research institutes of the Caribbean region

Constitute an indispensable underutilized source of knowledge, expertise

and institutional resources and facilities. This project is a major first step toward establishing a regional program of action to reinforce and expand these resources and apply them to the solution of the energy problems of the Caribbean Basin which are draining many of the national economies. On the other hand, the large potential for solar energy available in the area is not being properly exploited.

In this project, as far as we know, for the first time a representative group of the human resources in academic institutions of the Caribbean Basin, members of UNICA, has been brought together to analyze, discuss and develop joint planning for cooperative research projects in conventional natural energy sources. This goal was successfully accomplished as shown in the workshop conclusions and recommendations.

As the third phase of the project, a solar energy utilization Seminar/workshop for the Caribbean Basin was carried out June 7-10, 1963 at the University of Florida in Gainesville. This report consists of two substantive parts and a set of complementary appendices. The conclusions and recommendations are extracted from the solar energy workshop but also include very important inputs from the previous two workshops, on wind and on biomass, which were funded under previous grants from NSF and the Exxon Educational Foundation.

2. Publications

One technical paper describing the procedures used to carry out

this project was prepared. The paper entitled "Development of Alternative Energy Science and Engineering in the Caribbean" was prepared by JR. Bonnet, Jr. and W. Koehler and presented at the II Interuniversity

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Symposium of Energy held at the Universidad de Santiago de Chile, November 14-19, 1983. & copy of the paper is included as Appendix D.

A second paper, "Status of Renewable Energy Programs in Caribbean Islands" by the same authors, is being prepared based on the conclusions of this project and other information gathered. This paper will be presented at ENERGEX '84 in Regina, Saskatchewan, Canada, May 14-19, 1984.

3. Workshop Site and Content

The Solar Energy Utilization Workshop was organized and carried out by the Solar Energy and Energy Conversion Laboratory (SEECCL) of the University of Florida. The International Training Center for the Training in Alternative Energy Technology (TAET) was utilized as the site. In addition, site visits were made to the Energy Research and Educational Park (EREP) and other solar utilization projects in the Gainesville area. Faculty and administrative personnel for the seminar were drawn

from the TAET and SEECL programs.

The seminar stressed the fundamentals of solar energy utilization, emphasizing that the best available source should be used. Among the topics covered were characteristics of solar energy, measurement and modeling techniques for the Caribbean, heat transfer, preparation of materials, and standards and system optimization for tropical use. Applications for tropical elements were discussed and hardware prototypes shown and visited, including solar devices for water heating, space cooling, refrigeration, cooking, conversion to mechanical energy or to electrical energy, fresh water production, and the use of solar energy in preserving crops by drying and refrigeration. The papers "Solar Energy Conversion Research and Development at the University of Florida" and "The International Training Center in Alternative Energy Technology," both by Dr. Erich Farber, Co-principal Investigator of this project, describe the setting and many of the demonstration sites visited. A copy of the first of these two papers is included as Appendix E.

Demonstration sites of actual solar installations in the city of Gainesville were toured. This visit included 2 solar powered coin

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laundry, apartment buildings, a hospital, and the Gainesville airport.

This latter is the world's largest solar powered building.

The workshop schedule is included as Appendix A.

A list of lecturers is included as Appendix C and a list of the participants as Appendix 8.

Summary of Recommendations

The detailed conclusions and recommendations are included as Part II] of this report. & summary of the main conclusions and recommendations follows:

4, Publication of a Caribbean directory of human and institutional resources in energy.

Establishment of a research endowment fund.

4. Establishment a program of regional faculty interchange.

4. Development of curriculum on energy conversion and alternatives courses.

? Development of training programs in maintenance of energy hardware.

f. Establishment of UNICA speakers bureau.

9. Establishment of extramural science student programs.

h. Acquisition of video equipment.

4. Acquisition of solar insulation and wind measurement instrumentation.

J. Establishment of energy audit programs.

k. Establishment of a certification program for solar equipment.

1. Transferring solar equipment manufacturing technologies.

1. Energy system design, performance and maintenance workshop.

Cooperate and participate in energy demonstration projects of

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of the Caribbean Development Bank and the Organization of American States.

5. Evaluation

A comparison with previous workshops is not possible since not all UNICA contact persons attended all three; some attended only two of the workshops. The general feeling is that the project is moving toward establishing a unique base for a more solid program to enhance the capabilities of UNICA member institutions.

On the last day of the seminar/workshop an evaluation questionnaire was distributed to each participant to elicit his views and reactions toward the activity. The results of the evaluation indicate that 55% of the respondents gave an overall rating of "good" and 27% of "excellent." The tabulation included here shows the percentage of the ratings given by the participants of the three UNICA alternative energy workshops.

A general review indicates that the solar workshop (#3) was superior in organization and logistics to the previous two. From the standpoint of speakers, workshop discussion and overall, the wind workshop (#1) was rated better than the others, but there is not a significant overall difference. In all cases more than 75% of the participants agree that the workshops were successful to a greater or lesser degree in meeting UNICA goals.

It is important to remark here that non-UNICA contact persons who attended the seminars were also given the opportunity to answer the questionnaire. As one of the respondents wrote: "Keep up the good work,

your life (in the Caribbean) depends on it.?

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EVALUATION OF

UNICA WORKSHOPS

J. WIND / 1981 IIT. BIOMASS / 1982 IIT. SOLAR / 1983

(25 respondents) {13 respondents} ?(i respondents)

Stating Se feting Pasting

cca

Excelent, 27.18 31 45

Good 56.6 6 55,

Fair 138 3 0

Poor 0 0 0

2. Speakers

Excellent 13.8 15 2

Good 72.8 62 55

Fair 13g 3 18

Poor 0 0 °

3. Workshop Discussion

Excellent 55.2 15 a

Good 44.8 6 55

Fair 0 16 9

Poor 0 0 3

4. Overall

Excellent, 22.8 0 27

Good 6 92 55

Fair 0 8 cr

Poor 0 0 0

5. UNICA Goals

Very successful 2 ° 27

Successful 40 46 2

Sonewhat successful 12 46 2

Not successful 4 0 0

Unaware 23 8 18

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SHOP CONCLUSIONS AND RECOMMENDATIONS

The participants in the Solar Energy Utilization Workshop met on June 10 to discuss the completion of specific UNICA organizational and research plans and the planning of cooperative projects in order to develop and extend the scientific and engineering capability of Caribbean universities and research institutes so that they may be able to contribute effectively to the wider use of alternative sources of energy

in the region.

In the previous two alternative energy workshops, on wind and biomass, the participants were divided in three discussion groups: education and training needs, research and development needs, and demonstration needs. In this workshop, it was decided to work as one group to discuss the same three topics.

The group began reviewing the recommendations made in the previous workshops and decided to pursue the recommendations on a practical and reliable way taking into consideration the work going on at the Caribbean Development Bank, CARICOM, the Caribbean Meteorological Institute, etc.

Following is a review of the major conclusions and recommendations:

2. Education and Training

A human and institutional resource assessment of Caribbean technological and scientific capabilities is needed immediately. In many cases foreign expertise and/or organizations are used due to a lack of knowledge of the capabilities available in the Caribbean region. This situation prevents further development of the Caribbean resources available, and in many cases results in inappropriate or irrelevant recommendations by foreign consultants, which often generate deep resentments. Of course, in cases of non-available expertise, the new

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knowledge if properly channeled (technology transfer), is generally well received.

The publication of a directory of Caribbean resources will serve in part to solve this problem. The first issue of the human and institutional Caribbean Basin directory should be prepared and a method devised to update it at least annually. The directory should also include a list of energy courses that are offered in the region. The directory should be given angle distribution.

UNICK institutions feel that the greatest contribution in solar technology could be in preparing and reviewing technical curricula to teach energy saving techniques and renewable energy alternatives. This is especially true in the case of welders, electricians, plumbers, electronic technicians, and others: Special emphasis was given to the enhancement of the techniques to maintain/conservate energy producing equipment such as diesel generators and gas turbines. Many failures and poor performance of this equipment are usual occurrences in the area. UNICA should also support and work closer with CARICOM in their seminars and training courses.

The establishment of energy auditors training and certification procedures and the development of standards, including certification for solar alternative hardware, was given high priority by the group. Energy audit technicians are almost non-existent and UNICA institutions should establish curricula and courses to train energy auditors and help the government to establish an energy management certification program. The establishment of extramural science student programs for high school

students was also considered,

In addition, the establishment of a UNICA speakers bureau to address professional and social groups on energy matters was recommended. The UNICA contact persons in this project could form the nucleus of such regional energy speakers bureau. In this way the university could also participate as a catalyst of social change in the Caribbean society.

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The need for funds for regional interchange of professors was also recommended. This is especially necessary among different linguistic Groups since because of their language, culture and political ties, technical information transfer between them is in many cases non-existent. This project has greatly helped in establishing the first Tink for a comonality of scientific interest, and some interchange on a direct basis has already occurred. A more formal and extensive program was recommended,

UNICA member institutions are aware of the proliferation of courses and educational materials, including latest technical conferences, that are available in videotape but many of them do not have the videotape and television monitor to be able to benefit by renting or buying this material. The group understands that the acquisition of such equipment Will be of great help in their academic and faculty continuing education,

3. Research and Development

After reviewing some of the research and development efforts going on at specific institutions and taking into consideration the regional role of UNICA, it was decided that the mjr role that could be played in the Caribbean Basin is to help enlarge and improve the solar data base available. Almost none of the UNICA institutions has @ single solar insulation or wind measurement instrumentation. On the other hand, the Caribbean Meteorological Institute has ongoing programs to

measure solar and wind potentials in the Eastern Caribbean, the Dominican Republic and Puerto Rico. A program to regionalize, standardize and provide additional adequate measuring instrumentation at UNICA institutions is regarded as the first RAD priority. Proper mechanical, analyze, collate and distribute the information are needed.

ms to col~

The other area of commonality of interest was energy system design and maintenance. The interaction between components fails in many cases. More important, the group feels that the matching to end

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Users and the cultural impacts of new technology to their countries is @ highly sensitive area that needs further research. The new technology must closely meet the social and cultural needs. The evaluation of projects existing or under construction could be an important grass roots? contribution: of UNICA to the region.

From the standpoint of technology transfer the group recommended

that UNICA assume an advisory role in transferring knowledge about manufacturing technologies processes. The solar water heater is a good example where already local manufacturers of flat plate collectors have established themselves in Barbados, Trinidad, Puerto Rico, Dominican Republic and other countries. The certification process of such products to meet local needs could also be catalyzed by UNICA. Solar cookers, solar stills, solar distillation units, solar steam, solar air Conditioners, wind turbine generators, etc., are examples of technologies that, with proper training, can be manufactured locally in many cases. Manuals and training through UNICA member institutions to private concerns could help such possibilities.

It was recommended that UNICA establish a research endowment fund to be distributed on the basis of strict competition of scientific proposals and peer review. The established foundation for higher education operating in the Colombia could be used as a model.

The UNICA newsletter should be expanded to include information related to RED projects and courses at member institutions. UNICA contact persons could become a scientific correspondence bureau for the newsletter.

4, Demonstration

After a long discussion, it was decided by the UNICA contact persons that it was not realistic to recommend specific energy demonstra-

tion projects. This decision was based mainly on the fact that there

Seems to be an adequate number of energy demonstration projects in the

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Caribbean sponsored by the UN, the World Bank, IADB, OAS, USAID, CIDA, CARICOM, etc., and even if they are of interest to the universities of the region at present that has a lower priority when compared with other ?more urgent needs.

WICA's intention is to cooperate as much as possible with established programs of CARICOM, CDB and OAS.

5. Conclusion

It was concluded that UNICA should undertake the preparation of @ proposal to implement the recommendations referred to above. The program delineated in this report is realistic and has been developed by the Users after more than two years of discussion and three workshop meetings. It is anticipated that it could be carried out in about three years with a budget of about \$300,000. The proposal should include three annual review meetings involving the UNICA contact persons. Be-

sides carrying out the review, it is recommended that three specific topics be used for presentations/discussions at the meetings. The three recommended topics, in order of preference, are: (1) technology transfers (2) energy systems designs, performance and maintenance; (3) science and technology.

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TOF APPENDICES

Workshop Schedule

List of Participants

Seminar Lecturers Resunés

Bonnet, Juan A., Jr. and Koehler, W., 1983. "Development of Alternative Energy Science and Engineering in the Caribbean," presented at the 11 Interuniversity Symposium of Energy, University of Santiago, Chile, November 18 to 19, 1983.

Farber, Erich &., 1974. "Solar Energy Conversion R&D at the University of Florida," Buildings Systems Design, February/March.

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June 8/83

June 9/83,

June 10/83

APPENDIX A

?SOLAR ENERGY UTILIZATION WORKSHOP

1206,

1300

0830

1000

1030

1200

1330

0830

1000

1030

nus

1200

1330

1430

1500

3530

1630

0830

1205,

?June 7-10, 1983

SoneouLe

Lecturer

Farber

Farber

Pagano

Soderstrom

Ferber

Soderstrom

Ferber

Pagano

Soderstrom

chav

Farber

Bush

Bonnet

Bonnet

Topics

Welcome and Introduction

Solar Energy: An Overview

Coffee Break

Characteristics of

Solar Radiation

Solar Measurements and
Modeling for the
Caribbean

Lunch

Tour of TAET and EREPY

Heat Transfer Properties
of Materials Collectors

Coffee Break

Standard and Systems Opti-
mization for Tropical Use

Lunch

Tour of Solar Facilities
in Gainesville area

Applications of Solar
Energy

Coffee Break

Applications (continued)

Applications in Tropical
Climates

Lunch

Agricultural Applications

Photovoltaics

Coffee Break

End Use Matching

Workshop (Group Discussion)

Workshop (Group Discussion)

Closing Luncheon

?TACT * Training Alternative Energy Technology Center

EREP = Energy Research and Education Park

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SOLAR ENERGY UTILIZATION WORKSHOP

June 7-10, 1983

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APPENDIX 8

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APPENDIX C

SEMINAR LECTURERS RESUMES

ERICH A, FARBER

Dr. Farber holds the rank of distinguished service professor at the University of Florida. He is an internationally recognized pioneer in the field of solar energy and has dedicated more than a quarter of a century to the SEECL at the University of Florida. This is one of the largest solar energy laboratories with national and international recognition. Under his leadership the TAET program was initiated at the University of Florida.

He has traveled world-wide as an invited consultant to many countries. In addition, he served as a consultant to USAID and VITA. The idea for the TAET for the third world participants, in fact, came from the idea of efficiency in disseminating information by bringing the participants to the University of Florida.

QUAN A, BONNET, JR.

Dr. Bonnet is Director of the Center for Energy and Environment Research of the University of Puerto Rico. Previously he was Assistant Executive Director for Planning and Engineering of the Puerto Rico Electric Power

Authority.

Or. Bonnet received his B.S. in Chemical Engineering from the University of Michigan in 1960 and his Ph.D in Nuclear Engineering in 1971 from the Same university. He is a registered Professional Engineer, Certified Energy Auditor and Chemist. He is currently the President of the Board of Examiners of Engineers, Architects and Surveyors of Puerto Rico. He is Associate Professor at the Gayanin Technological University College and a member of the System-wide University Board.

He was Technical Director of the XVII Convention of the Pan American Union of Engineering Associations (UPADI-82) held in San Juan in Au-

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gust 1982. He is the Chairman of the Science and Technology Commission Of the Caribbean Association of Universities and Research Institutes (UNICA). He is also a member of several energy and environmental advisory

He is a member of the

Puerto Rican Academy of Arts and Sciences and the New York Academy of Science. He was honored with the 1981 Mobil Award for outstanding scientific accomplishments in Puerto Rico.

sory committees in Puerto Rico and the U.S.

He has published numerous articles in scientific journals and many of his technical papers have been included in conference proceedings or abstracts,

KENNETH G. SODERSTROM

Dr. Soderstrom has been a faculty member of the Mechanical Engineering Department of the University of Puerto Rico (UPR) for over 20 years.

Most recently he was the Associate Director of the Center for Energy and Environment Research (CER) of UPR. As Associate Director of CEER he was responsible for the Mayaguez laboratory operations which included three of the five scientific divisions of the Center, namely, Solar, OTEC and Marine Ecology. For over a decade Dr. Soderstrom has been dedicating his research efforts to development technology transfer in alternative energy through programs of CER. He has traveled extensively throughout the Caribbean area in relation to international programs of CEER. His most recent research and publications have been concentrated on application of solar energy to tropical environments. He is presently on sabbatical leave from UPR and is a Visiting Professor in the Mechanical Engineering Department of the University of Florida and participates actively in both TACT and SEECCL programs.

ROBERTO PAGANO

Dr. Pagano is the Technical Director of the TAET Program, a position he has held for the last four years. He has traveled extensively throughout Africa and Europe and is multi-lingual in English, Italian

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and French, In addition to his involvement with teaching and technical Direction of the TAET program, between sessions he makes follow-up visits to 25-2 consultant to countries of the participants' origin for additional training and advice in adaptation of the appropriate energy technology. Dr. Pagano also brings to this program his experience in energy, resources, and environment system analysis in which he was involved at MITRE Corporation, prior to his appointment as Technical Director of the TAET Program.

MARTINO. BUSH

Dr. Bush is one of the regular faculty members of the TAET program. He has been with the program for over two years and teaches in many areas of alternative technologies, such as energy needs and uses, including use of different fuels, decision analysis, solar energy collection and Storage. His basic background is in fuel technology and chemical engi-

peering. He has lived in the U.K., Canada, and for three years in Trinidad as @ lecturer at the University of the West Indies.

KHE VAN CHAU

Dr. Chau is an Assistant Professor in Agricultural Engineering, University of Florida, specializing in grain drying and storage, and solar energy. His Ph.D. dissertation (from the University of California) was on solar collectors. Dr. Chau is a native of Viet Nam and worked in that country for several years in agricultural engineering and became the Director-General for Planning and Technical Affairs, Ministry of Agriculture before returning to the U.S. in 1975. He has extensive experience in tropical, developing countries. He is familiar with, and has visited the Philippines, Thailand, Taiwan, and India. Dr. Chau has been the lecturer in charge of solar crop drying for the "Training on Alternative Energy Technologies during the past 2 years. He has also served as an instructor in many short courses and workshop on solar crop drying for Florida county agents. He is the author or co-author of numerous technical papers on solar collector design and analysis, and solar drying under hot and humid conditions.

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11 SIMPOSIO INTERUNIVERSITARIO DE ENERGIA

Santiago de Chile, Noviembre de 1983

DEVELOPMENT OF ALTERNATIVE ENERGY SCIENCE
AND ENGINEERING IN THE CARIBSEAN

Juan A. Bonnet, Jr.*

Center for Energy and Environment Research

University of Puerto Rico

Wallace C. Koehler, dr.

Center for Energy and Environment Research

University of Puerto Rico

Abstract. This paper describes 2 pilot project designed to improve the

capabilities of Caribbean universities and research insti-

tutes in helping solve the energy problems of the region. Most of the

region is almost completely dependent on imported petroleum to satisfy

its energy needs. That dependency has exacerbated economic problems,

with the escalation of petroleum prices in the past ten years. A potential solution to reduce both the high degree of dependence and economic costs is to develop other energy systems. The region is blessed with solar, wind, ocean, biomass, and geothermal resources that could be exploited to reduce and displace oil consumption.

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

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

?Chairman of the Science and Technology Commission of the Association of Caribbean Universities and Research Institutes (UNICA).

The project described in this paper was carried out with support from the U.S. National Science Foundation under Grant No. INT-6300757 and previous NSF grants. The authors acknowledge this support with appreciation.

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A. Introduction

The 51 inhabited islands of the Caribbean archipelago have a total area of about 230,300 square kilometers and a total population of approximately 20 million. It is a complex region, strategically located, with a diverse ethnic, cultural and political base. It is a mosaic not only of independent states but entities having varying relationships with the United States and European powers.

The Caribbean community has a very rich potential in inexhaustible alternative energy sources. In addition to geothermal energy, which is abundant in locations such as St. Lucia, many feasible inexhaustible solar-related alternative energy sources exist. This is largely due to

the fact that the Caribbean, lying between latitude 10°N and 25°N, has 2 resulting year-round solar insolation of approximately 2000 BTU per square foot per day. A few of the more common of the solar-related resources are trade winds, ocean waves, moderate ocean currents, extensive ocean thermal masses, year-round biomass production, agriculture, and mariculture. Table 1 summarizes geographic, demographic and other data for the Caribbean region. Only one of these island-states produces fossil fuels. This is Trinidad, which has 1/40th of the land area and 1/20th of the population. The size of its foreign exchange reserves places it among the first six of all the nations in the Commonwealth. The other 50 island-communities depend on imported fossil fuels for 99% of their energy requirements. It is estimated that 37,950,000 barrels of oil per year are imported by these

Since the 1950s, the Caribbean has made strenuous efforts to diversify its economy by providing more jobs through industrialization and by expanding tourism. As in so many developing countries throughout the world, these early efforts were almost totally based on the use of imported fossil fuels. By the end of the 1980s most of the archipelago will be a potential disaster area unless the dependence on imported fossil fuels is reduced and the use of alternative sources of energy is greatly increased. Four of the major obstacles to progress are: (a) Lack of manpower; (b) inadequate research in the use of existing technologies.

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

A system of cooperation is of great importance in a region whose history has been one of fragmentation and dependence on external markets and external authority. & Tong history of dependence on external rulers has left many of the Caribbean peoples a bitter legacy of resentment, even of hatred. The ideological conflicts that characterize the con-

temporary Caribbean are evidence of this, just as the boat people from Cuba and Haiti and the illegal immigration into Puerto Rico from the Dominican Republic are indicators of growing poverty and discontent. Aid from the industrialized countries is important, but it cannot of itself provide a solution. Caribbean development depends, in the last resort, on the capability of the Caribbean people to analyze their problems and, with assistance from others, to find solutions for them, Cooperative relationships between individual United States and Caribbean

fersities, though valuable in themselves, do not fully meet the need for transforming donor-recipient relationships into 2 large partnership of scholars and scientists.

Because of the urgency of the energy situation in the Caribbean, it is crucial to the orderly economic and cultural development of the re- Sion that a degree of energy self-sufficiency be developed at an early date. If this does not occur, disastrous consequences will result as the price of imported fuel escalates beyond the reach of all but the fost well-endowed (or most heavily subsidized) communities, thus forcing ?them into either a position of complete dependence on those who have O11, oF into @ position of extreme poverty, beyond which economic and political survival may become impossible.

The universities and research institutes of the Caribbean region constitute an important under-utilized resource of knowledge, expertise and institutional facilities. This resource is under-utilized largely because (a) the region is not looked upon as a whole; (>) because there 4s little comunication among the scientists of the regions (c) and

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because the Caribbean

being intimately involved in the development process. Yet great deal

Of valuable work is being done in its universities and research insti-

tutes. Consequently it is essential that Caribbean universities and

research institutes should be utilized to their fullest to achieve

greater self sufficiency in basic necessities such as energy and food.

The Association of Caribbean Universities and Research Institut ions

(UNICA) has sought to provide a forum of cooperation necessary to de-

velop solutions to the problems of enera y in the Caribbean. To do so

UNICA has launched @ program to foster cooperative research effort aimed

munity does not perceive its universities as

at assisting im the introduction of alternative energy solutions.

This project provided for and depended upon the active cooperation

of universities and research institutes from the Spanish, English,

French, and Dutch speaking Caribbean. The levels of research work

varied, ane required the more advariced centers to provide technical as-

sistance to those which are less advanced. In this way the effort to

find viable programs for the use of alternative sources of energy was shared by all the institutions involved. The project attempts to make full use of the network of Caribbean institutions, providing a mechanism for training at appropriate centers within the region, and involving many participants in research programs and in the preparation of a comprehensive regional program for using alternative sources of energy. Through this method, the quality of science and engineering research was improved, and the potential for stimulation for technology transfer and for further cooperative efforts were realized.

The project focused on the need for the countries of the Caribbean archipelago to achieve greater self-sufficiency in energy; on the role

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

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

Development

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

1, Mechanism for Achievement

a. The Association of Caribbean Universities and Research

Institutes (UNICA)

In the late 1960s, perceptive Caribbean educators saw the future development of the Caribbean community as a matter of regional concern. To meet their common needs they created UNICA, a voluntary association of Caribbean universities and research institutes dedicated to positive, carefully directed efforts for Caribbean development.

Founded in 1968 by 16 universities located in ten Caribbean countries, the organization now has 45 member institutions representing a constituency of more than 300,000 students and 30,000 faculty.

Expected Significance

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

3. Project Description

a. Overview

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

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The work was carried out in three phases. The first Phase involved planning activities, identification of UNICA institution! contact persons and background literature searches. The second phase involved the holding of three workshops dealing with various aspects of the alternative energy problem: on wind, biomass and solar

utilization, The third phase involves the completion of research plans and proposals resulting from the workshops, the preparation of education and manpower training plans, and the compilation of reports on the alternative energy data base and organization which has been generated. Funding for this project came from grants from the U.S. National Science Foundation and the Exxon Education Foundation.

b. Procedure

1. Phase One

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

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

* Or. Erich Farber, Director of the Solar Energy Institute, University of Florida, Gainesville.

* Professor Gerald Lalor, Pro-Vice-Chancellor of the University of the West Indies, Kingston, Jamaica and Head of the Department of Chemistry.

* Or. Juan A. Bonnet, Jr., Director of the Center for Energy and Environment Research of the University of Puerto Rico.

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

* Dr. Howard P. Harrenstien, Civil Engineering Department, University of Miami.

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

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(3) Contact a1 UNICA member universities and ask their chancellors or presidents to appoint university faculty liaison representatives to work on the alternative energy program. In order to implement the project this Commission requested from the universities and research institutes which are members of UNICA to appoint official contact persons knowledgeable in energy matters who could provide information on the energy state of affairs of their respective islands, participate in workshops, and serve as a focus to initiate educational and research activities in their institutions. A questionnaire was circulated to all UNICR contact persons and two follow-up notices were sent to assure maximum response. This experience reflected the reality of lack of information about energy and renewable energy matters in the Caribbean.

After a search in general and specialized libraries and other information centers in the Caribbean, it was found that the best data were available at the Caribbean Development Bank in Barbados, the Island Resources Foundation in the Virgin Islands and the Center for Energy and Environment Research in Puerto Rico.

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

(5) Receive and compile the results of the questionnaires at CER.

This activity was completed and resulted in the paper "Energy Alternatives for the Caribbean". The paper represents the most up to date general description of renewable alternative energy projects and potential in the Caribbean and constitutes a major contribution of this project.

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

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2. Phase Two

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

(1) Wind as an Energy Alternative for the Caribbean

(2) Biomass as an Energy Alternative for the Caribbean.

(3) Solar utilization.

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

Paper was prepared titled "Alternative Energy in the Caribbean."

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

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

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

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ergy and then to electricity without involving the Carnot cycle and the

unavoidable thermodynamic losses which are associated with such energy conversion. In addition, the Caribbean is an area in which the trade winds are predictable and of sufficient level of power. It is logical to concentrate on this source as one which could provide an early payoff. The chances of early success should motivate and stimulate the growth of science and engineering capabilities in local universities, since needs for manpower training and local engineering capability should be quickly realized. Because of existing expertise and presence of the Caribbean Meteorological Institute and the Caribbean Development Bank, the wind workshop was held in Bridgetown, Barbados in December 1981.

Biomass was the second form of alternative energy considered since agriculture has traditionally been the principal source of income in the Caribbean. The year-round solar insolation, coupled with frequent rains

sufficient magnitude to provide @ reason-

?on windward shores, provides one of the finest environments on earth for prolific biomass production. As imported fossil fuel prices rise, it is critical that this biomass potential be converted to clean-burning substitute fuels, such as methanol and ethanol. There is reason to believe that ethanol production from sugar cane is already cost-effective, particularly if attention is given to the productive use of

wastes which are generated by the process. This second workshop was, held in San Juan, Puerto Rico at CER in April 1982,

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

3. Phase Three

Phase three constitutes the reporting and implementation phase.

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

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

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

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

1. Project Application Potential

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

1. Solar hot water

Cogeneration

Hydroelectric

Electricity from solid waste

Small wind machines.

Large wind machines

Electricity from bagasse

8. Solar ponds

5. Photovoltaics

10. Ocean thermal energy conversion

11. Geothermal energy conversion

12. Other

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

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

alternative energy sources for the

Workshop Suma)

1. Wind as an Energy Alternative for the Caribbean Workshop

The first UNICA workshop was carried out in Bridgetown, Barbados

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

(1) Education and Training Needs

(2). Research and Development Needs

(3) Demonstration Needs

Each of the workshop session groups produced a report.

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

(1) A resource assessment of human and institutional capabilities, wind resources, and demonstration projects in the region is needed,

(2) After the first recommendation is implemented, detailed action plans and proposals to implement the other workshop recommendations are needed.

(3) Sources of funding to continue this project and to implement the most important recommendations should be sought.

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

2. Biomass as an Energy Alternative for the Caribbean

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

This workshop was carried out immediately following the Seminar on Fuels and Feedstocks for Tropical Biomass II held in San Juan, Puerto

Rico on April 26-27, 1982. Many of the UNICA contact persons were also able to attend this seminar, which provided them with more thorough knowledge of biomass as an energy resource.

The biomass workshops indicated that the group feels that:

(1) Research, development and demonstration projects in biomass as an energy source must be established in the Caribbean region. Funding to carry out such projects is critically needed,

(2) Provision of training and education on Caribbean tropical biomass is a must,

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

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

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

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

funding.

3. Solar & Wind

The third workshop was held June 6-10, 1963 at Gainesville, Florida.

During this workshop the basics of solar energy conversion and Utilization were covered and extended to specific problems found in the Caribbean Basin. Presentations on solar radiation measurements and modeling in the Caribbean, Heat transfer, materials, collectors, applications of solar thermal, dryers, distillation,

ion, photovoltaics and

system analyses were delivered. All presentations were video-taped.

Visits to field installations were carried out.

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

Research, development and demonstration projects in Solar, biomass, wind, and other appropriate energy systems.

2. Expand Education, and training in appropriate energy technology and uses through the UNICA network. Increase university and research institute interest.

Data are often insufficient in the Caribbean to permit the level of planning desired. Develop a data collection and analysis capability drawing on existing regional expertise.

4. Expand internal UNICA communications through newsletter, workshops, etc.

5. Analyze experience and develop an expanded appropriate energy network,

6. Develop and maintain the practice of collaboration research and exchange of data among UNICA members.

7. Seek external funding to finance increased energy technology development and transfer in the region.

D. Conclusion

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

oa

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Most promising beginning to resource utilization and petroleum substitution.

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

This paper points out some of the impediments to cooperation as well as delineating a system of cooperation. One is insufficient data.

Another is the inchoate network among universities and research institutes in the Caribbean. This paper describes an effort for a more realistic plan for education, training, research and development and for deeper data collection and evaluation,

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

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ARERRIY F

RESEARCH & DEVELOPMENT

UNIVERSITY OF FLORIDA

SOLAR ENERGY CONVERTERS:

AT THE UNIVERSITY,

DR. ERICH A. FARBER, Professor of Sciences

Director, Solar Energy & Energy Conversion

Researcher

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Solar Baking

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BUILDING STEWS DESIGN PROFESSIONAL DEVELOPMENT SECTION

week

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during certain parts of the year

could be preserved from spoilage

and thus preserved for use during

the hot part of the year. This requires

refrigeration and for remote areas

refrigeration without electricity, large

refrigeration may be well balanced and

Some of our early work along

these lines was to heat to either

high temperatures by concentrating

using solar energy and then

circulating the hot oil around the

generator of an ammonia absorption

refrigeration system, Fig.

This picture is somewhat out of

focus since it "the applications

thus far dealt with solar energy it

tration but we put here since

ictus actually our first attempt

We've seen however, that 3

figuration. without concern

Folds much "more. promise since

for concentrating devices can also

utilize the diffuse portion of solar

Sundays

shown before the Scan unit shown

in Fig. 15. ie Pit pipe collectors

to get out the ammonia

of the system This ammonia por

SS consented and then expanded

Providing the cooling effect by

evaporation After having done so

to work the ammonia vapor it reabsorbs

in the ammonia absorber of

the system into the water to

Fig. 15 and 18 show a schematic

eliminates! the? primary fund and

Reduces the heat losses by" pros

Solar neat to get into the systems

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fa good day

1 shouldbe pointed out a

that allthe applications mentioned

sofa id not require concentrated?

ton of solar energy, and therefore

?ould tie the diffuse portion of

Slr rere and: work? even om

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Simply are in phase: When the sun

shines hottest ?the need for rete?

Solar Energy Concentration

For some uses, however, higher

FEBRUARY MARCH 1978

with flat plate, non-concentrating

Collectors are needed. If this is the

case, then "concentration" is called

Parabolic trough collectors are stationary designs but

are a good and better ones

to follow the design in Fig. 10.10

shows a simple high temperature

Absorber Tube consists of a number of

parallel tubes with a pipe running

along the focal line of the parabola

as the "system" or "parabolic

(Wong is inclined at the

local latitude. Depending upon the

diameter of the pipe, the

yearly solar energy

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Solar Power Plant

1 better efficiency is desired.

then a linear parabola can be
used which are allowed to follow

{Re a un she mpl frm hey

source steam to operate

Small team same, which is

it drives a small generator and

lights up six bulbs this demonstrates

that like The 22 ohm abe

Series is the equivalent of 800

watts of electrical heat

Alaree linear parabolic a=

sorter is shown a Pig, IP having

Siimension of 6 feet wide

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cover reduces the losses from the

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Thar unit has. beoh used to
broduce steam for the operation of
{factional horsepower steam ee
fine to provide 80F ol fo operate

Molar Feigert, et

Other methods of concentrating solar energy are lenses both of glass and other materials (including quartz lenses), but they are not widely used because of their cost in large uses and their weight. However Fresnel lenses specially made from plastic sheet with grooves cut or embossed so as to reflect the rays are produced

and can be of large size and

Then weight. The lenses shown in fig. 20's of this type and can reach a temperature of 2000°C

A very effective way of concentrating solar energy is to use flat pieces of reflecting material (for better suits they can even be slanted or curved) such as mirrors of reflecting metal surfaces and arrange them in such manner as to

reflect the solar radiation on to

Spot Front surface

Types have been but with thousands

of these mirrors used in some

(of the Tange solar furnaces in the

Solar Cooking

Types are shown in Fig. 2h

where they are concentrated

Spot board will make this board

Such mirrors are

also be setup in different pattern

like the one shown in Pe 32 where

Circular pattern heating the food

Spot board will make this board

?higher concentration, and thus
higher temperatures, and smaller
focal regions are desired then t=
{er still mirrors are needed of
continuously curved surfaces can
be employed. In this manner ex?
of optical quality can be made But
these are very expensive and there
superficial into the use of

?Two such mirrors of fair quality
are shown in Fig 23, the one on the
{eh being strong enough to mold its
shape? by being properly formed,
The one on the Pn Being sup

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Solar Furnace

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Solar Reciprocating Engine

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BU'LOMNG SYSTEMS DESIGN PROFESSIONAL DEVELOPMENT SECTION

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