

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH ~ SANT PUERTO RICO STATE
SOLAR PORT PROJECT Final Report FY 1981 Submitted to: SOUTHERN SOLAR ENERGY
CENTER under Contract No. SSEC-1200-C-230-0016 October 1, 1982

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1981 Prepared by: William Ocasio Salvador Lugo

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Introduction: The State Solar Support Program sponsored by the Southern Solar Energy Center (SSEC), was established in July 1979 to facilitate the regional and institutional coordination fundamental to the effective promotion and rapid commercialization of solar technologies. Its established goals have been to augment the capacity of state agencies in renewable resource activities and to provide state assistance to SSEC in pursuit of its mission.

To respond to these goals, CEER has utilized the SSEC in support of the solar commercialization components of its Energy Assessment and Analysis and Community Awareness efforts. Through these, the Puerto Rico State Solar Support Project has provided staff support to CEER planning and programming efforts in each one of our divisions that are involved with solar and renewable energy technologies.

The Center for Energy and Environment Research (CEER) began its participation in the Puerto Rico Solar Support Program in July 1979. It was continued during FY 1980 and FY 1981. William Ocasio has served as Project Director and State Solar Contact until February 1981, when Salvador Lugo was named State Solar Contact, with Mr. Ocasio remaining as Project Director. Able secretarial support has been provided by Sylvia Medina and Blanca Maldonado.

1.0 AGENCY RESPONSE

1.1 Goals, Starting in 1957 as a nuclear science oriented research and

The training institution, the Center, evolved into a highly diversified research and development organization working in the areas of energy and environment. This transition was made possible by an agreement between the University of Puerto Rico and the U.S. Department of Energy in 1976. Ever since, CEER has actively sought and developed projects aimed at tapping the inexhaustible resources of sun, wind, and sea, while also exploring the potentials inherent in recycling, conversion, or elimination of the waste products and pollutants of modern society. More specific goals of the institution are:

1. To provide the focal point for energy research in Puerto Rico, to help the island achieve energy

independence while contributing to DOE's effort to enable the entire nation to achieve the same goal. In this sense, CEER is a microcosm that can easily be amplified to other areas.

2. To help Puerto Rico develop the scientific, engineering, and other trained personnel needed for the future in energy, and in related environmental areas.
3. To continue research and training programs in environmental sciences and technologies.
4. To serve as a center for international cooperation in the energy and environmental fields, particularly for scientists and technicians from tropical and subtropical areas in the Caribbean, Latin America, and the sun belt of the U.S. mainland.

It should be stressed that the nature of these goals is a reflection of the surrounding environment and the perceived local needs. For instance, agriculture has been declining rapidly in Puerto Rico, and it could use some profitable crops, like energy cane. The emerging poultry industry may have a problem with waste disposal. The same problem is faced by the dairy industry. Hence, these animal wastes could be tapped for energy production, while at the same time solving the environmental problem. In more general terms, climate has influenced our work. Close proximity to cool ocean water helped bring about experiments. The prevailing

Winds are an asset for passive cooling. And there is plenty of sun to be tapped. Thus, it is against this background that we have pursued our more specific objectives.

Objectives Division: This division aims to develop an optimum strain of energy cane which will serve the dual function of supplying Puerto Rico's need for fermentable solids and a waste product that can be burned to produce steam and electricity. Considerable success has already been achieved in the creation of new, highly efficient crop management techniques.

The field of biomass candidates for energy has been narrowed to the most promising short, intermediate and long rotation varieties to include trees and water hyacinths. Wood terrestrial species are being evaluated as sources of boiler fuel, cellulosic feedstocks and base stocks for methyl alcohol production.

Feasibility studies are underway to determine the shape and operation of the bioconversion facility, one that would produce high-test molasses and electricity.

Bioconversion: Two primary aspects of this program include studies of terrestrial and marine energy farms; anaerobic digestion systems for the production of methane; ethanol from agricultural wastes; utilization of animal feedlot wastes and solid waste landfill for energy recovery.

It is hoped that through our bioconversion program, we will be able to:

- Produce, use, and demonstrate the technical and economic feasibility of fermentative biogas production,
- Instrument and monitor existing or newly constructed biogas production facilities,
- Develop alternate uses for anaerobically fermented waste residue and effluent,
- Work with local industry to help reduce environmental pollution and petroleum derived energy dependence,

- Optimize and demonstrate hydrogen production by biophotolysis,
- Act as a central technology data source for tropical biogas production information and expertise.

Ocean Thermal Energy Conversion: As a potential source for commercial supplies of electrical.

"Energy. Ocean Thermal Energy Conversion (OTEC) offers a viable solution as one of the most economical sources of energy yet conceived. The "fuel" for generating electricity is free and limitless, which will quickly recover the rather formidable initial equipment cost. CEER has already made significant progress in overcoming the major obstacles to the development of an OTEC pilot plant. CEER's ocean platform has run longer, continuously, than any other data gathering station. What makes CEER's explorations in OTEC unique is the fact that the work is being performed at what may be the best site in the United States for a pilot plant. Off Punta Tuna, 2000 foot deep water is found within two miles of Puerto Rico's coast and close to an electrical grid that could utilize an abundant amount of ocean energy.

Solar. The principal objective of the Solar Division is to harness solar energy for application in industrial and agricultural situations. Puerto Rico is an excellent laboratory because of its location in a tropical zone.

1.3 GEER Response to SSP

To enable the Center to respond to the State Solar Support Project, a new program was created with enough breadth to encompass ongoing solar activities as well as new areas of broad economic analysis and community awareness. Thus Energy Assessment and Analysis and Community Awareness (EXACA) came into being with Mr. William Casio, a Ph. D. Candidate from MIT, as Project Director. His training in economics and energy matters was crucial in getting this effort going. This program has been recently renamed Analysis and Applications. Energy Conservation and Technology Transfer Activities are also included. As the areas developed, Mr. Salvador Lugo was brought in. His experience in economics and energy planning helped carry out our responsibilities. During this year part of Mr. Casio's time has been devoted to Institutional Planning and Development. These activities indirectly support all the solar and renewable energy programs at CEER.

Page Break--- 2.0. Impacts and Accomplishments 2.1 Identifiable Advances

As was mentioned before, one direct result of the State Solar Support Project was the creation of the Energy Analysis and Applications Program with a strong emphasis on a development approach. This involved utilizing existing funding to obtain further financial assistance for undertakings that would strengthen the program's capabilities to deal with renewable energy resources. Along these lines, funding was obtained from the Department of Energy (DOE) for a study on the impact of the increase in electricity prices on low-income families in Puerto Rico.

It is our hypothesis that this upward move in electricity rates will greatly increase the need to turn to renewable energy resources. The Community Awareness Area started growing when funding was obtained from the National Science Foundation to study the possibility of energy self-sufficiency for Culebra, an island municipality off the East Coast of Puerto Rico. The objective of the project is to

explore the possibility of reducing Culebra's dependence on imported energy.

To this end, a series of workshops were started to explain to the public the options available to them in terms of renewable energy technologies. Four out of six workshops were held with an estimated attendance of 95 persons. The subject of discussion on each occasion was: energy production technologies, wind energy, biomass and bioconversion, solar and conservation.

Expansion of the Energy Analysis area continued when we obtained financial assistance from the Association of Caribbean University and Research Institutes (UNICA) and from Exxon Corporation to hold four seminars (Barbados, San Juan, Jamaica, and Venezuela) on engineering aspects of renewable energy technologies.

Ocasio and J. A. Honnet, Jr. wrote a paper for 'The International Engineering Week' held in Mexico in 1980, on the energy situation in Puerto Rico. The paper will soon be published by the Puerto Rican Academy of Arts and Sciences. As a sequel to conversations held with Argonne Laboratories, we were visited by them for possible participation of the Energy Analysis Group in the database development phase of an energy plan for Puerto Rico and the Virgin Islands.

Mr. Ocasio participated in a symposium on biomass for agriculture in Puerto Rico. The activity was sponsored by the University of Puerto Rico. Both Mr. Lugo and Mr. Ceasto contributed to the text and graphic illustration of the Annual Report, particularly in regard to solar energy. Mr. Ocasio contributed a substantial amount of his time to institutional planning. We coordinated with SSEC in an effort to get local architectural firms interested in passive cooling. Very good information was obtained from SSEC on the subject and we passed it on to the architectural firms. We requested and obtained information from SSEC on industrial process heat and other renewable energy resources. We also obtained a slide show and accompanying text on the same subject. On our part, we responded to several requests for information from SSEC.

Advances in other areas of CEER were as follows:

MAJOR BIOMASS PROJECTS:

Sugarcane and Tropical Grasses: A study of three sugarcane varieties revealed the following trends: (a) there are increased yields with a delay in harvest frequency of from 2 to 12 months (b) narrow row spacing is ineffective (c) napier grass is superior to sugarcane when harvested at less than 6-month intervals and (d) there is greater bulk in first ratoon-yields over plant-crop yields.

Harvesting: Tests have been conducted on high density cane with several types of harvesting equipment. Best results, with commercial promise, were obtained with a Klaas whole cane harvester, a modified Kaas harvester, a V-cutter with

Subsequent Loader and a V-Outter with Continuous Loader: The Moody Species, *Eucalyptus robusta* has clearly emerged as the leading candidate in terms of survival and yield.

Major Bioconversion Projects:

Energetic Pig Farm: A CEER monitoring program was authorized by a farmer who had constructed three anaerobic digesters with sloping bases as part of a project to become energy self-sufficient. Data were gathered on waste treatment and energy production.

Mess 1 Methane: One of several biogas projects undertaken recently was a food waste experiment using leftovers from the U.S. Army mess hall at Fort Buchanan in San Juan with productive results.

Gas and Fertilizer from Rum Waste: The objective of this research was to convert rum waste into a valuable energy and fertilizer resource by utilizing tubular fermenters. Biogas produced in the process can be used to fire boilers and produce steam that will drive turbines. The "Fuel" is renewable and abundantly available.

Major OTEC Projects:

Biofouling Tests: In Situ biofouling of simulated OTEC heat exchanger tubes at an OTEC site. Biofouling and heat transfer as a function of cleaning frequency and season of the year were determined between January 1980 and March 1981. During this period of time, both 5052 aluminium and grade 2 titanium tubes were examined.

Corrosion Analysis: Corrosion analysis of zinc diffusion coated extruded 3004 aluminium OTEC heat exchanger elements is currently being determined.

Surfactant Test: Open cycle OTEC surfactant studies have been concluded.

Drogue Study: An extensive drogue study has been conducted to determine the flow direction and velocity from an OTEC plant if it were to be sited at Punta Tuna.

Cable Fouls: The OTEC Division also conducted a study funded by the Simplex Wire and Cable Company to determine the biofouling of eight different proposed OTEC power cables.

Major Solar Projects:

Solar Data - Measurements and Modelling: The Division operates five solar data measuring stations throughout Puerto Rico.

A computer program has been developed for a mathematical model of this data in a format amenable for utilization by scientists and engineers for basic research use and design information.

Solar Collector and System Test Facilities: Solar testing loops have been designed and constructed for low-temperature (less than 100°C) collectors, either liquid or air, and medium-high temperature (200°C) liquid collectors. All test loops are designed per American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standards.

Collector Development: Solar collectors have been developed for use in tropical climate conditions from low temperature (less than 100°C) to medium-high temperature (300°C) for utilization in

industrial heat processes.

Solar Air Conditioning: An experimental facility for testing drying of humid air has been developed, utilizing silica gel and solar energy as the source of regeneration energy. Various system configurations have been investigated.

Demonstration Projects: The Solar Division has participated in a number of demonstrations:

- a) Photovoltaics-thermal system for utilization in habitats - Phase 1
- b) Solar industrial process heat system for a food industry - Phase 1
- c) Development and testing on-site a medium-temperature concentrator for steam production at a pharmaceutical plant in Puerto Rico.

Solar Pond Research: The Division is currently involved in a research and development program in solar pond application for industrial technology transfer - Panama. Participation in an energy assessment master plan for Panama is a current activity.

Another advance worth mentioning is the strengthening of the Division with the appointment of Dr. George Pytlineki as its Director.

Accomplishments outside CEER include the following: Act 11 was enacted by the Puerto Rican Legislature to amend the income tax to define solar equipment as any equipment that will convert solar energy into direct or indirect usable energy, and apply deductions for solar water heaters to all.

Solar equipment. Other actions to promote solar were the approval by the Office of Energy of a solar code aimed at guaranteeing efficiency and engineering adequacy of solar equipment.

One last advance in solar was the completion of the award-winning design of a passive cooling structure to house the Center. Mr. Pedro Muiz was the architect in charge and the award was given by the American Association of Collegiate Schools of Architecture. In terms of solar educational tools developed by CEER, we published, in collaboration with the Mayaguez Campus of the University of Puerto Rico, a 75-page handbook in Spanish describing the principles and basics of solar hot water heater construction. Another publication was the Proceedings of the Symposium on Fuels and Feedstocks from Tropical Biomass, held in San Juan, Puerto Rico on November 24 and 25, 1980.

3.0 EVALUATION

There is no doubt that CEER's area of public awareness (Culebra Project) that began with the advent of the SSS will have an ongoing impact for years to come. The experience gained in information dissemination and interaction with the community is one that will help CEER in the promotion of renewable energy resources with different citizen groups. Another ongoing impact,

although it affects solar somewhat indirectly, is the study of the effect of increased electricity rates on low-income families. There is no doubt in our minds that the results of the study will emphasize the need to develop solar. The Assessment Area has also helped provide technical information from SSBC and indirect support to the other divisions. Ongoing work in these areas are as follows: In the biomass area, a consortium has been formed to develop the technology that would go into a biomass conversion and power facility. Design studies are currently underway. With respect to biogas, a research project has been established to design, construct, and demonstrate an energy-integrated pullet and layer farm incorporating energy and

Nutrient Recovery. "The use of other renewable energy technologies, such as solar and wind conversion, have also been incorporated into the project.

6. The primary objective is to produce sufficient energy internally to operate a farm and minimize dependence on costly, non-renewable energy resources. The infrastructure continues to be improved. The major facility of the Division is the research vessel platform which consists of a modified 115 foot long army LCU. The vessel platform has been extensively refurbished so as to enable it to remain moored at an open ocean site for at least one year at a time and perform OTEC bio-fouling and corrosion studies.

In addition to a wet laboratory for biological studies and a facility for acquiring and analyzing heat transfer data, the vessel also has been refurbished so that extensive physical, chemical, and biological oceanographic studies can be performed.

In the Solar Division, work is in process for the construction and monitoring of a solar system for the production of industrial process heat for the food industry. There are also residential and industrial photovoltaic demonstration projects; and solar pond development. In the international area, there are alternative energy assessments and training programs for several countries.

We have been describing the advances made at CEER in regard to research and applications of renewable energy resources. But Puerto Rico continues to depend on petroleum for 98% of its energy needs. Moreover, the cost of electricity to the consumer is sharply up. As an alternative to oil, coal was thought of, but discarded.

The only attempt that seems to have had some small results to ameliorate the problem is the use of solar hot water heaters and conservation. But the bulk of the problems still remains. Thus, we must rely on solar to continue to probe for alternatives, capitalizing on local conditions. For instance, utilizing existing agricultural facilities and infrastructure for growing and processing.