

ALTERNATIVE TECHNOLOGIES: RESEARCH AND DEVELOPMENT
BY CEER IN PUERTO RICO

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Proceedings of the 1984 Annual Meeting of the American Section of
International Solar Energy Society, 5-9 June, 1984, Anaheim, California.

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ABSTRACT

Research and development of alternative energy technologies in Puerto Rico is described. Completed and ongoing activities of the Center for Energy and Environment Research (CEER) of the University of Puerto Rico are discussed. Projects on biomass, solar thermal energy conversion, ocean thermal energy conversion, energy and technology assessment, marine and terrestrial ecology, and energy outreach are presented. Funding for this work comes from the Federal and Commonwealth governments, industry, foundations and international organizations. CEER's activities emphasize the needs of Puerto Rico and the Caribbean.

1. INTRODUCTION

Puerto Rico's geographical location, climate, infrastructure, economic development, available human resources and its bicultural and bilingual characteristics make it a unique place for research and development activities in alternative energy sources. Within the island's 3,435 square miles are six ecological zones and 26 soil classifications representative of southern Florida, the Caribbean, Central America, northern South America and large regions of Africa and Asia. Puerto Rico is a mosaic of tropical land, water and botanical varieties. The island is looked to for technical guidance in the region. In Puerto Rico, as in other Caribbean islands, the need for petroleum and its high cost are the driving forces in the development and implementation of alternative energy technologies.

The Center for Energy and Environment Research (CEER) of the University of Puerto Rico (UPR) is committed to the research and development of a variety of alternative technologies. The four steps required for the widespread use

of a new technology are research, development, demonstration, and commercialization. For technologies designed for semi-tropical or tropical areas such as Puerto Rico, on-island demonstration is often a necessary step toward market acceptance.

2. CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

In 1957 the Atomic Energy Commission, acting under President Eisenhower's Atoms for Peace Program, established a center for training Puerto Rican, Latin American and Caribbean personnel in peaceful uses of atomic energy. Research and development were pursued for nearly two decades. In the 1970s a shift in federal energy policy caused by the world oil crises prompted the transformation of the Atomic Energy Commission into the Energy Research and Development Administration (ERDA). Subsequently, the scope and focus of Puerto Rico Nuclear Center research changed through mutual agreement between ERDA and the University of Puerto Rico. Thus in 1976 the Center for Energy and Environment Research (CEER) was established to study new energy sources for Puerto Rico and their environmental aspects. In the process ERDA, then followed by the U.S. Department of Energy (DOE), agreed to provide institutional and programmatic support. The CEER budget in FY 83-84 amounted to \$3.2 million with funds coming mainly from UPR institutional funds, DOE contracts, P.R. government funds, competitive DOE grants, local agencies, international agencies and public enterprises. This is an example of the successful transition from a federally sponsored research laboratory to one sponsored by a University (UPR).

During FY 81-82, CEER celebrated its 25 years of active service in scien-

tific and technology research, development and management. In recognition of its research accomplishments, DOE declared CEER to be, "the most important Hispanic research center in the United States."

sugar cane industry in the Caribbean Region. These activities can stimulate employment in agriculture through the cultivation and use of new tropical grasses such as energy cane for biomass, molasses and sugar. The CEER

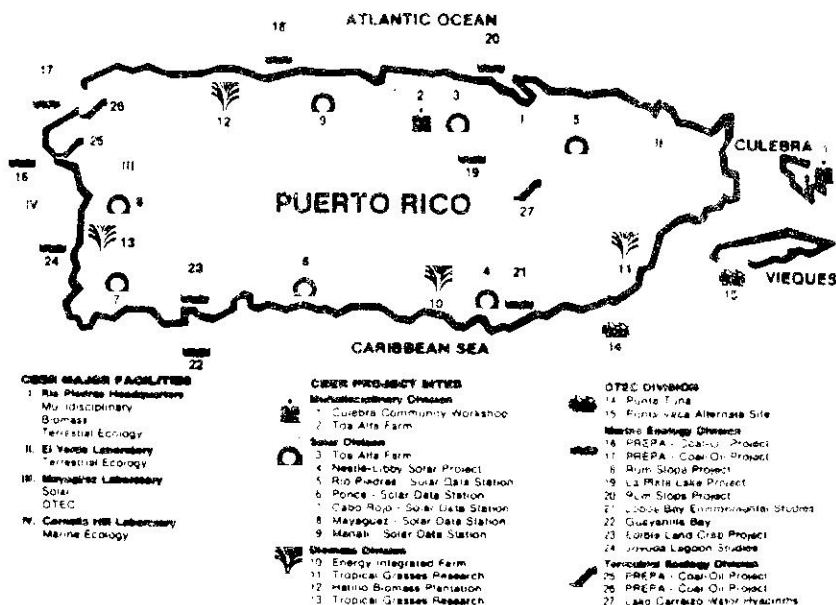


Fig. 1. CEER's Major Facilities and Project Sites.

3. RESEARCH AND DEVELOPMENT IN PUERTO RICO

The areas of primary concern for research and development (R&D) in Puerto Rico are biomass, solar thermal energy conversion, wind energy conversion, water quality, waste disposal, ecological effects of energy production and utilization, resource management, technology development and commercialization, and energy and policy assessment. CEER's mission is to provide scientific, technical and managerial expertise in several interdisciplinary areas, and to develop commercially viable, environmentally safe technologies that could provide the government and industry with solutions to energy and environmental problems. Figure 1 shows CEER's major facilities and project sites.

3.1 Biomass

In the agricultural sector, CEER programs dealing with sugar cane, energy grasses, and bioconversion could stimulate commercial activities. The development of "energy cane" by CEER scientists has brought attention to a possible reorganization of the ailing

activities in this area have two phases: an agricultural phase during which the biomass is produced, and an industrial phase during which the crude biomass is converted into a marketable form of energy. This energy cane technology developed in Puerto Rico is being promoted in the Caribbean by CEER.

The production of tropical grasses for energy was proven to be economically viable for regions with tropical agriculture capabilities. The use of these grasses, as proven by CEER R&D efforts, could enable energy cane production/utilization operations to continue on a year-round basis. The principal candidates evaluated by CEER to date include napier grass, Sorghum and Sudan Grass hybrids, and sugar cane managed specifically as an energy crop or "energy cane."

CEER is involved in the planning and pre-implementation activities of the use of biomass as fuel to generate an additional 20 MW electric power capacity for the Puerto Rico Electric Power Authority. The study addresses supply and demand, use of existing or new sugar mill boilers to burn bagasse and tropical grasses, technical aspects

of combustion and transportation, and co-financing of the project. The experience gained in Hawaii and Florida has been employed to evaluate the use of existing facilities in Aguirre, Arecibo, and Rincón for this purpose.

As part of the biomass technology research and development activities, studies were initiated with tropical forest species and water hyacinth. Woody terrestrial species were evaluated as sources of boiler fuel, cellulosic feedstocks and base stocks for methyl alcohol production. Analysis was also performed on the production and conversion of water hyacinth and vegetable residues to low Btu gas.

CEER is cooperating with local farmers and industries in various bioconversion activities. These activities are oriented toward finding technically and economically feasible ways to: produce fermentative biogas from local materials, instrument and monitor new biogas production facilities, develop uses for fermented waste residue and effluent, and help local industry and agriculture turn polluting wastes into commercially viable products such as methane gas and fertilizer. This research has demonstrated the feasibility of converting livestock wastes into valuable energy feed resources through proper processing and management techniques in Puerto Rico.

A major CEER project having far reaching significance for Puerto Rico and less developed agrarian tropical nations is the "Energy-Integrated Farm System" (EIFS). This is one of eight EIFSs funded by the U.S. Department of Energy. The farm selected for the project is located in Juana Díaz on the south coast of Puerto Rico. This is a 500 head dairy operation situated on 20 acres of a 200 acre farm. The new energy integrated farm system is designed to fulfill two functions: (a) to produce greenfeed, electricity (up to 90% of farm needs), and high protein feed substitutes from manure; and (b) to establish waste management in compliance with Puerto Rico's environment quality control regulations. The construction of all energy systems, including two biodigesters of 264,950 liters (70,000 gal) capacity each, will be completed in the spring of 1984 and the farm integrated energy operation will start in the summer of 1984.

3.2 Solar Energy

In 1980 under a DOE grant to CEER, a working relationship was established

with the Puerto Rico subsidiary of the Nestlé-Libby Company to identify an appropriate technology for the design of a 4,645 sq m (50,000 sq ft) solar process heat system for the company's local plant. The design stage of the project was implemented.

The same year a faceted compound parabolic collector was developed by the CEER research/engineering staff. The collector was then fabricated and installed at the plant of Roche Products, Inc. in Manatí, Puerto Rico. The project passed through typical R&D stages such as evaluation, engineering adaptation, prototype testing, and development before the approved system was installed at the plant premises for demonstration purposes. Also in 1980 the U.S. Department of Energy awarded CEER the design of a 150 kW concentrating photovoltaic system for the Medical Center in San Juan.

A CEER scientist invented and developed a novel solar water heating system built into the louvered tropical window widely used in homes and buildings in Puerto Rico and the Caribbean. Valuable experience was gained in moving from the engineering development of the concept to a near market ready project which can be commercialized with a minimum of funds. Several companies manufacturing windows in Puerto Rico were approached, and the process was initiated to identify financing resources for the further development and eventual marketing by local industry of this tropical window solar water heater.

A relationship has also been established with food processing companies in Puerto Rico. Discussions are in process to develop and implement salt-gradient pond technology for process heat generation as part of CEER's solar energy conversion activities.

Shallow solar pond technology was brought to Puerto Rico with assistance from the Lawrence Livermore Laboratory (LLL) in California. Funds were obtained through a DOE grant with the user co-financing a 21.4 sq m (230 sq ft) pond system. The system was installed in January 1983 in Mayagüez, Puerto Rico, to deliver up to 1003 liters (265 gal) of hot water per day to a local school cafeteria. At the beginning of 1984 CEER solar scientists designed and installed a second shallow pond of 40 sq m (430 sq ft) area to heat water for the swimming pool showers at the Mayagüez campus of the University of Puerto Rico as part of energy conservation efforts. Both installations are being evaluated.

The U.S. Department of Energy, through the Puerto Rico Office of Energy, financed another energy conservation project. Some 300 fiberglass solar collectors of a newly invented concept were built at CEER. The 650 sq m (7000 sq ft) parabolic collector array will assist an absorption air conditioning system of 100 ton cooling capacity being installed at the CEER research site on the west coast of the island (Mayagüez). This is a good example of CEER's application of in-house engineering and manpower resources.

From research and the operation of six solar radiation measuring stations during the last six years, a solar radiation map for Puerto Rico was published.

3.3 Wind Energy

A wind measuring program was initiated at CEER in 1982. It is planned to integrate this program with wind data collection by the P.R. Office of Energy. Six wind measuring stations installed at sites characterized by high winds are now operating in Puerto Rico. The collection of wind data at properly selected sites is critical; existing data on the island comes from weather stations at airports and other installations that usually do not have proper wind magnitudes.

One R&D machine of 1 kW power output was installed by CEER at its headquarters building in San Juan; a second one of 4 kW rating is being installed in Arecibo. Seven demonstration wind machines will be installed around the island in the near future by the P.R. Office of Energy.

A novel concept of a variable geometry Darrieus wind machine was introduced by CEER. Work on a complex theoretical model of this new turbine was completed in 1983 and the results of the computer simulation were published. A computer program for wind plant siting in Puerto Rico was developed by CEER for further study of wind resources on the island.

3.4 Ocean Thermal Energy Conversion

Puerto Rico has one of the best sites for an Ocean Thermal Energy Conversion (OTEC) power plant. The right water depths and temperature gradient are found close to shore and near an existing electric power grid. In 1978 CEER began a project to study the variability of oceanographic parameters pertinent to the construction of an OTEC plant at the site of Punta Tuna, Puerto Rico. This study was funded by DOE.

A parallel study was also performed for the Puerto Rico Electric Power Authority of an alternative OTEC site off Punta Vaca at Vieques Island. Measurements taken by CEER scientists confirmed the thermal suitability of both Punta Tuna and Punta Vaca as OTEC sites. The surface water temperature is 26°C-29°C (79°F-84°F) throughout the year and the temperature is 6°C (43°F) at 1000 m (3281 ft) depth.

OTEC was investigated at CEER as a potential source for the generation of electrical energy. On the site biofouling and corrosion tests were conducted on different potential materials for an OTEC heat exchanger such as alloys of aluminum and titanium tubes. The tests were conducted so as to produce recommendations for material and cleaning techniques for future, commercially viable heat exchangers. The R&D work was performed off Punta Tuna in a specially equipped converted LCU boat under grants from Argonne National Laboratory and NASA. This research can contribute to accelerating the development of a durable and reliable heat exchanger for future OTEC power plants. An underwater study was also performed for OTEC power cable biofouling and corrosion to serve as an indication of the product's commercial potential. The project consisted of design, construction and deployment of 16 cable samples at depths of 8 to 60 meters (26 ft to 197 ft). The project was financed by the private sector.

CEER scientists also studied an open cycle OTEC system under a grant from DOE. Various experiments were performed on the use of a mixture of surfactant with water to form foam that is used to drive an open cycle OTEC. These OTEC R&D activities give CEER valuable in-house knowledge and data concerning the operation parameters for an OTEC plant in Puerto Rico or elsewhere in the Caribbean; Curaçao, Jamaica, Saint Croix and Venezuela have expressed interest in the concept.

3.5 Marine and Terrestrial Ecology

The CEER R&D activities in marine ecology are related to coastal and lagoon management and the environmental impact of human activities. The marine ecology program identifies ecological perturbations that result from chemical and thermal pollutants, and then presents alternatives for the preservation and development of marine resources in the coastal areas of Puerto Rico. Studies have been conducted on zoo-plankton, bottom organisms, turtle grass beds, mangrove communities, and

marine animals in the vicinity of a fossil fuel power-generating plant that has been in operation for over two decades near Guayanilla Bay. Organisms in Guayanilla Bay are exposed to elevated temperatures, and hydrocarbons and heavy metals discharged from nearby petrochemical and chemical plants. Studies were conducted to establish the concentration and variability of various chemical constituents in the water and sediments.

A study of Joyuda Lagoon was done to collect the physical, chemical and biological information needed to describe the ecology of this well known natural body of water in Puerto Rico. This data was used in the subsequent planning and management of the resources in the Lagoon and surrounding watershed. A similar study was done for one of the most important water reservoirs in Puerto Rico, La Plata Lake.

A study conducted by CEER in 1980 and funded by the Puerto Rico Aqueducts and Sewer Authority investigated water treatment and the cleaning potential of water hyacinths.

In a 1981 project initiated at CEER under a grant from the Puerto Rico Electric Power Authority (PREPA) a site characterization and environmental impact assessment were done for an oil/coal burning power plant planned for the north coast of Puerto Rico.

In a 1982 project, funded by the U.S. Environmental Protection Agency, the larvae of a commercial species of crab were successfully grown to stages suitable for use in mariculture. The commercial potential of the project awaits further development.

A recent 1983 contract with the Puerto Rico Aqueducts and Sewer Authority calls for five mixing zone permit studies for regional wastewater treatment plants in Puerto Rico. The study is developing methodologies for using tropical marine organisms as assays for toxic substances.

The tropical rain forest station of El Verde is used by CEER's terrestrial ecology staff as a unique laboratory for tropical ecosystem studies. Research on the structure and function of island rain forest ecosystems is being done under a DOE funded project to study cycling and transport of materials likely to be effected by industrial development in Puerto Rico.

Under contract with the U.S. Forest Service CEER completed in 1982 a study

on the altitudinal distribution, habitat affinities and life history of the Puerto Rican boa, a federally listed endangered species.

A study of the entire watershed in northeastern Puerto Rico was also done under the terrestrial ecology program. This study investigated the interrelationships among the climate, vegetation, flora, fauna, soils and human inhabitants; and their combined influence on the hydrologic cycle of the watershed.

3.6 Technology and Energy Assessment

Besides technical R&D activities, CEER conducts technology evaluation, policy assessment and socio-economic studies.

As part of regional efforts by the Southern Solar Energy Center to accelerate the use of solar and other renewable energy sources, the Puerto Rico State Solar Support Project was started at CEER in 1979. The objective of this project was to provide information about and to perform a survey of the Puerto Rico private sector falling under the project.

In 1980 a grant was received from the National Science Foundation for the project "Community Participation in the Development of Energy Self-Sufficiency for the Island of Culebra." This project was initiated with a series of seminars on the island of Culebra. The objective of this project, which ended in 1982, was to assess the technical, economic, environmental and socio-political aspects of the Culebra inhabitants energy needs, and the means to achieve energy self-sufficiency. The study was conducted through a series of workshops and interviews, and a survey of 150 households.

In 1980 CEER designed a computer program entitled Methodology for Economic Optimizing to provide researchers with a tool to get a first approximation of the economic potential and problems of a technology process in the development stage.

In 1981 CEER received a grant from the DOE Office of Minority Economic Impact to analyze the distribution and socio-economic impacts of changes in electricity prices and policies on low-income families in Puerto Rico. As the project progressed, cooperation was established with the Puerto Rico Department of Labor and Human Resources to survey electricity consumption, appliance ownership and demographic characteristics of the population.

During 1982 CEER performed a computer study and sensitivity analysis of various conventional and renewable energy sources. Sensitivity analyses were developed for electric power generation using coal, nuclear energy, oil, biomass, OTEC, and solar energy.

During 1980-1983 CEER carried out several international projects, among them: evaluation of renewable technologies potential in the Republic of Panama; technical, economic and administrative status evaluation of projects of the Caribbean Development Bank and the CARICOM Secretariat (sponsored by the U.S. Agency for International Development), and assistance to the Dominican Republic in wind and solar resources assessment. The Center for Energy and Environment Research has a current Indefinite Quantity Contract (IQC) with the U.S. Agency for International Development to provide technical assistance in the development of renewable energy technologies.

3.7 Outreach Program

Technology development in Puerto Rico and the Caribbean depends on an understanding of the economic, social and political impact of relevant technologies. The Center's outreach program includes workshops, conferences, seminars and exhibitions.

As part of CEER's service to the Puerto Rican community, the Center takes part in community awareness programs and public information activities. CEER staff participate in lectures and serve in an advisory capacity to a number of private and public organizations that have an interest in research, education or technology transfer.

In 1980 CEER in cooperation with the Puerto Rico Department of Education implemented a Summer Research Apprenticeship Program. Also in 1980 CEER was a principal sponsor of the First Caribbean Conference on Energy and Development which brought together a multidisciplinary group of about 300 participants from 29 countries.

In 1981 CEER received two grants, one from the National Science Foundation and one from the UNICA Foundation, for a series of workshops to foster cooperation among members of the Association of Caribbean Universities and Research Institutes (UNICA) in developing renewable energy technologies. Three workshops have taken place: in Bridgetown, Barbados (1981); in San Juan, Puerto Rico (1982); in Gainesville, Florida (1983).

CEER serves as the Secretariat of the Caribbean Institute of Resources Management (CIRM). In 1982 CIRM co-sponsored a week-long Foresters Training Workshop in Saint Lucia together with St. Lucia's Ministry of Agriculture and the U.S. Institute of Tropical Forestry. Ten Caribbean Islands were represented during the workshop.

In 1982 CEER co-sponsored the following conferences in San Juan: Second National Conference on Renewable Energy Technologies, First Pan American Conference on Energy, Fuels and Feedstocks from Tropical Biomass II Seminar. The latter seminar brought together a group of about 100 participants from industry, the scientific and academic community, and the Federal and Commonwealth governments for a one-day discussion and analysis of current and projected R&D. CEER also co-organized the XVII Convention of the Pan American Association of Engineering Societies (UPADI) and the XV Latin American Chemical Congress. CEER/UPR with the P.R. Chemists Association and CERI/UM* are planning a week-long international conference on energy, Energy for the Americas, to take place in Puerto Rico in conjunction with the First Pan-American Chemical Congress in October, 1985.

4. CONCLUSION

The activities described present a wide range of R&D projects completed or in progress in Puerto Rico in collaboration with several Commonwealth and Federal government agencies. Commonwealth funds via the University of Puerto Rico System have been replacing Federal funds during the last four years. This shift has prompted the reorientation of some of the R&D activities at CEER to be directed more toward the technological needs of Puerto Rico and the Caribbean. Puerto Rico has taken a leading position in the development of its natural resources and is ready to contribute to the development of other Caribbean islands through training, technology transfer and cooperative R&D activities.

*Clean Energy Research Institute/University of Miami.

