CEER-X-161 THE QUEST FOR ENERGY SELF-SUFFICIENCY IN PUERTO RICO by Dr. Juan G. Bonnet, Jr. Director, Center for Energy and Environment Research, University of Puerto Rico. Presented at the Conference on ENERGY PLANNING FOR THE U.S. INSULAR AREAS organized by Congressional Research Service, The Library of Congress.

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THE QUEST FOR ENERGY SELF-SUFFICIENCY IN PUERTO RICO. Incentives and financial arrangements are already developed, providing opportunities for investment in Puerto Rico. We envisage four types of opportunities: (1) investment in equipment or systems that will substitute for imported fuels. This is the revised version of a paper presented at the Conference on Energy Planning for the U.S. Insular Areas, sponsored by the Congressional Research Service of the Library of Congress, Washington, D.C., May 12-13, 1983. "GPO Box 3682, San Juan, Puerto Rico 00936.

(2) manufacture of such equipment for Puerto Rico and the rest of the Caribbean and Latin America; (3) creation of new businesses dedicated to the development and supply of alternative fuels from renewable sources; and (4) development of a technology transfer service industry from Puerto Rico to the Caribbean and Latin America. CEER studies indicate that, all other prices constant, the increase in oil prices from 1973 to 1979 induced an increase of more than 130% in an estimated producers price index, excluding industry markups, which implies double-digit inflation even when there is no increase in other prices. This increase has resulted in an estimated loss of 58,000 jobs and $1,326.

Million USD was auctioned to Puerto Rico. This alone shows that there will be expenditures for indigenous energy alternatives in the short term, which would result in reduced future spendings and a reduced drain of funds. The Center for Energy and Environment Research exists to carry out the necessary research and development, and to transfer the technology to the Caribbean and Latin America. This center, a part of the University of Puerto Rico, was founded in 1987 as the Puerto Rico Nuclear Center (PRNC), and reorganized in 1976 as CEER. It is presently focusing on research and development in the fields of alternative energy and the environment. Last year, the Center received the U.S. Department of Energy's Exceptional Public Service Award for its scientific research accomplishments. In presenting the award, Dr. Alvin Trivelpiece, Director of DOE's Office of Energy Research, declared CEER as having become "the most important Hispanic research center in the United States," and Puerto Rico as having rapidly developed into an ideal laboratory for Caribbean and subtropical energy research. Through 1961, federal funds supplied CEER with substantial support on the order of $2 million yearly. Since then, federal funding has been severely curtailed. In order to partially compensate for the diminishing federal assistance, the University of Puerto Rico has increased its budgetary contribution to CEER. In fiscal year 1983, UPR provided $1.3 million, or about 40% of CEER's total budget. The rest of the funding comes from competitive research grants and contracts awarded by federal and local agencies and private industries. The federal government should ensure its leading role in supporting basic research and education in

solar related areas at universities. Advances in long term, high risk yet potentially high payoff areas such as photovoltaics hinge on the scientists and engineers who will devote their talent to these new technologies. Last year, CEER was granted a two-year project.

Indefinite Quantity Contract (IQC) by the U.S. Agency for International Development (AID). This may serve to facilitate technology transfer activities to the Caribbean region. CEER has already worked in Panama, Barbados, the Dominican Republic, and other Caribbean Basin countries. Several of CEER's major alternative energy achievements discussed here are now ready for reliable and economic commercial use. CEER has developed the "energy cane" and "energy grasses" concept under a five-year grant from the U.S. Department of Energy: it has developed a new type of solar energy collector with industry's participation; it has also established a solar insolation, wind, and microseismic data gathering network; it has designed and constructed a large solar air conditioning system, and is developing an energy integrated farm on the south coast of Puerto Rico. CEER has also carried out DOE-sponsored OTEC research in Puerto Rico, with special emphasis on biofouling and corrosion.

Oil Substitution Policy

The decrease in energy consumption and the temporary reduction in oil prices due to lower world demand are contributing to the postponement of concrete actions to find substitutes for oil as our primary energy source in Puerto Rico. This has been aggravated by the substantial reduction in federal allocations for solar energy research to CEER. If we want to assure continued development and a competitive and healthy economic climate, oil substitution should be one of our most important public policy priorities. We should plan now to move Puerto Rico quickly towards the attainment of a degree of energy self-sufficiency that will significantly diminish our dependence on foreign oil. A brief review of past and current efforts to diversify our energy sources should help place the problem in perspective. The ensuing discussion will take into account possible private industry involvement in such energy sufficiency endeavors. The biomass alternatives are the most promising of any plan leading toward energy self-sufficiency.

Self-sufficiency for Puerto Rico. Glonass can supply electricity more cheaply than coal or oil. (See Table 1 and Figure 3.) In 1981, CER proposed to revitalize the sugar industry by converting it into a supplier of high-test molasses and energy. This proposition is based on solid scientific information generated by the CER energy cane and tropical grasses research and demonstration project during the last five years.

The final cost analysis for production, including delivery, and energy balances indicates that locally produced biomass is unquestionably an economic and reliable energy resource with multiple benefits when managed specifically as an energy crop. If 7,000 of the acres now planted in sugar cane were gradually converted to energy cane, Puerto Rico could (1) Produce more than 13% of its electricity needs from local biomass at a cost lower than that of fuel oil; (2) Completely eliminate the heavy dependence of its rum industry on imports of molasses. Parenthetically, exports of rum provide one-seventh of the recurring revenues of Puerto Rico's General Funds and (3) Operate the sugar cane industry at a profit. As an energy alternative available today, CER's biomass program has been highly praised by CEER's Senior Scientific Advisory Committee as the "best in the Americas and, arguably, one of the best in the entire world." The U.S. National Academy of Sciences in its 1980 report "Energy in Puerto Rico's Future," concluded that biomass cropping has

probably the greatest potential among renewable energy sources. The report further recommended that the Puerto Rican government seriously consider establishing a pilot biomass-fired generating plant with a capacity of perhaps 10-20 megawatts. Three 20-mile units now in operation at the San Juan Steam Plant could be converted for this purpose. A sister unit of this equipment was sold to the U.S. Sugar Corporation in Florida and is now being used exclusively for burning bagasse to generate electricity. CEER is preparing a detailed proposal to establish a 20.

My biomass-fired generating plant in Puerto Rico. The adoption of biomass will also require a favorable agricultural policy, with a conscious decision to direct sugar cane trend toward production of bagasse under the "energy cane" management system. Solar-dried "energy grasses" would be a complementary fuel to ensure a continuous year-round supply of power. Biomass could also be developed on the island as feedstocks for our present and future new chemical industries. When the biomass development project was successfully completed last year, U.S. Department of Energy funding was terminated. However, biomass has not yet been adopted for use in Puerto Rico even though it constitutes the best available local energy source. The U.S. National Academy of Sciences study found that given vigorous development, biomass could provide as much as 30% of the island's electricity by the year 2000. Estimates from CEER and the PR Office of Energy agree with this (see Table 1). Consequently, financial arrangements are urgently needed to implement a biomass-fired plant before the sugar industry in Puerto Rico collapses completely. Other Caribbean islands such as Jamaica, the Dominican Republic, and Barbados are seriously considering this energy alternative. CEER is also conducting experiments with fast-rotation trees, grown in land unsuitable for other purposes, that can be harvested as energy crops. The species Eucalyptus robusta has produced biomass yields superior to commercial sugarcane. Energy Integrated Farm in Juana Diaz, Puerto Rico, CEER is conducting an important energy integrated farm project, one of eight such projects in the U.S. This project includes two 70,000 gallon digesters, a biogas-operated electric generator, greenfeed operation of Napier grass, soil conservation, the growing of fish and aquatic plants in the effluent lagoons, and a windmill for pumping effluent. This one-million-dollar project is funded primarily by the U.S. Department of Energy, with additional.

With support from the Puerto Rico Office of Energy, the private sector, and CER, waste energy from municipal solid waste is another viable biomass alternative for Puerto Rico. This can be achieved either by direct combustion or by methane generation from landfills. A number of such systems are being investigated by our municipalities, including San Juan and Caguas. In fact, the use of solid waste to produce energy in the San Juan metropolitan area has been considered and studied for more than twenty years. It has been determined that 20 mega-electric units are viable right now, provided power can be sold at long-range cost and not at marginal cost. At present, efforts to build the first plant with private funds are being aggressively pursued, and legislative changes have been proposed to make it financially possible. The proposed changes should be carefully analyzed to ease the adoption of this viable biomass alternative, which will also solve the waste handling problem of the metropolitan area and stimulate the interest of private involvement in alternative energy development in Puerto Rico.

Solar Thermal: The use of solar water heaters, of which approximately 20,000 are in operation today in Puerto Rico, solar ponds, and solar air conditioning can help to some degree in reducing oil imports. All are very susceptible to private investment as shown by several solar water heater factories currently in operation on the Island. The use and development of these alternatives should be encouraged as much as possible. Different studies indicate that individually, each of the above alternatives would supply at most a small percentage of our energy needs; hence, we should move

toward some kind of energy "mix." Also, during this year, CEER will complete the installation of a large solar air conditioning project in its Mayaguez facilities. The system consists of 300 parabolic fiberglass solar collectors designed by CER and manufactured on-site using local manpower, materials, and expertise. When completed, it will provide about 100 tons.

The text provides cooling to 32,000 sq. ft. of office and laboratory space. A solar salt gradient pond to generate process heat at an 8-foot processing factory is being designed by CEER. This project will be funded by the firm concerned and the PR Office of Energy. The relatively high capital cost of flat plate solar water heaters relative to electric water heaters has precluded their faster introduction in the market. Studies by the Southern Solar Energy Center in Atlanta indicate that Puerto Rico is fifth among the states in potential for the use of solar water heaters. There is a new generation of water heating systems that rely on more sophisticated and less expensive materials. Researchers have developed plastics that are more resistant to scratching and degradation by the sun's ultraviolet rays and more tolerant of high temperatures. They weigh less and their cost is as much as 25 percent lower than that of a conventional solar collector. CEER has already installed a small solar plastic shell pond with an area of 2 square meters on the roof of a private school in Mayaguez. The system will supply 135°F water to the school cafeteria. A similar, larger system is being designed to be installed at the swimming pool on the Mayaguez Campus of the University of Puerto Rico. This innovation will make the market penetration of solar heaters on the island more attractive.

There are about 75 locations in Puerto Rico suitable for wind machines of about 2.5 megawatts each. On the other hand, the 200 KW wind turbine generator (MOD-0) at Culebra is being decommissioned by the U.S. Department of Energy. The UPR Ponce University College is interested in reinstalling it there for educational purposes. According to Future Energy RED Corp., a Puerto Rican manufacturing firm, they have built and installed 42 Zeus 16 wind machines on the island. They are now in the process of finishing the installation of a 25 KW wind machine in a San Sebastián municipal building. This product, locally designed and manufactured, has been highly rated.

The text was featured among a group of four on the cover of Popular Science magazine in July 1962. The Zeus 16 machine is 15 percent efficient and has an automatic, centrifugally controlled variable pitch propeller which can be feathered and withstand winds of up to 100 mph. They claim their price is almost half that of U.S. manufacturers. The Puerto Rican government is giving a 50 percent tax deduction up to $3000 for each installation. The P.R. Office of Energy estimates that after biomass, wind can make the greatest oil substitution in Puerto Rico by the year 2000 (see Table 1). Now that "day rates" for drilling rigs have sharply declined, immediate attention should be given to petroleum exploration in Puerto Rico. Geological investigations using acoustic reflection methods have demonstrated the existence of interesting geological formations. Very thick layers of peat and rich organic sediments are found in all the coastal areas of Puerto Rico. The effect of fluctuating sea levels through geological times has contributed to the formation of extensive deltaic areas such as in the estuary of the Plata River west of San Juan. This area has sedimentary rocks of carbonaceous origin approximately 12,000-feet thick extending from the northern foothills to a considerable distance out to sea. Seismic reflection profile studies were conducted in this area during the planning of a nuclear plant by the Puerto Rico Electric Power Authority. Various interesting formations indicating the presence of dark spots in the reflections profiles (possibility of gas and liquid phases) were discovered. The most outstanding one had an estimated volume of

225 cubic kilometers. Even with a 1% content of extractable oil, this would be classified as a huge formation (above 16 billion barrels). Drills at this location would have to penetrate below sea floor for approximately 26,000 to 11,000 ft, water depth where drilling rigs or drilling ships would be located does not exceed 206 feet, which is well within limits.

Of present drilling technology, a positive drilling program in Puerto Rico would result in the lessening of our dependence on foreign oil to a significant degree and would consequently strengthen our energy position. We should find out now whether there is commercially exploitable offshore gas in Puerto Rico. Federal assistance would facilitate undertaking this task.

Another alternate source which could produce large amounts of energy is Ocean Thermal Energy Conversion (OTEC). However, OTEC has been virtually discarded for Puerto Rico, in spite of the fact that some of the best research has been carried out on the island and that we have some of the world's best sites. CEER studies on corrosion and biological growth on OTEC Plant components were successfully completed and resulted in the longest OTEC study ever conducted at an actual site. Puerto Rico's technical expertise in this area is nationally recognized. Studies made independently by PREPA and CEER indicate that an OTEC plant would be, after a nuclear plant, the most economic alternative for Puerto Rico in the 1990s. (See Figure 3.)

Hawaii has been favored over Puerto Rico in obtaining federal grants for OTEC development because of its greater political influence as a state and because of substantial Hawaiian government appropriations for its development. Both Hawaii and California are moving fast to replace their energy dependence on oil in spite of sharp reductions in federal funds for energy research.

Nuclear Energy: The Puerto Rico Water Resources Authority (PRWRA) recognized the need to diversify its energy sources as early as 1960. With the collaboration of the U.S. Atomic Energy Commission and the Puerto Rico Nuclear Center, PRWRA developed, constructed and operated the experimental BONUS nuclear power reactor in Rincon. Thus, Puerto Rico generated electricity from a nuclear reactor before any other Latin American country. The BONUS plant is a good example of an early high technology project successfully conducted in.

Partnership between the federal and Commonwealth governments. By early 1970, Puerto Rico was ready for the installation of a commercial nuclear power plant. A 600 MW nuclear unit was proposed for Aguirre and scheduled for operation in October 1976. Unfortunately, the project had to be discontinued some years later due to uncertainties in the geology of the site. After an exhaustive study of the island, a new site near Arecibo was selected and environmental studies approved by the federal regulatory agencies. In December 1975, the project was postponed indefinitely due to a combination of factors, including increased capital cost and social and political reverberations. At present, there are over 200 nuclear reactor power plants operating satisfactorily throughout the world. The United States stands at the crossroads of a decision on the nuclear option. If commercial nuclear power is to have a future, it must be economic, safe, and acceptable to the public. Some basic obstacles such as long-term radioactive waste disposal, regulatory uncertainties, high construction costs, and public misconceptions of safety risk assessments must be surmounted. Steps are being taken at the federal level to resolve these uncertainties; when they are solved, new nuclear power plants will blossom again. That would be the right time for U.S. manufacturers of nuclear power plants to develop and construct smaller units, such as 200 to 300 MW, suitable for the international market, which is now controlled by foreign manufacturers. A

federal/state/public consortium is recommended to develop small nuclear power plants. This option should not be discarded for possible future use in Puerto Rico since it continues to be the cheapest way to produce electricity (see Figure 1). Coal: In 1979, studies were started by the Puerto Rico Electric Power Authority (PREPA) to determine the feasibility of building a 900 MW coal-fired power plant. Environmental siting studies for this project were

The text has been corrected as follows:

Conducted by the UPR Center for Energy and Environment Research (CEER). In September 1981, PREPA decided to discard the plant project due to various factors, including a downward trend in energy sales and lower forecast of peak loads. In order to reduce its dependence on petroleum, PREPA is presently evaluating the conversion of two 450 MWe steam units at Aguirre for dual coal and oil firing. It has also announced that it has cancelled construction of additional generating facilities during this decade. CEER has proposed to PREPA an evaluation of burning coal-water slurries in existing oil-fired boilers. The main advantage of coal slurries for Puerto Rico is that they can be treated and transported as a liquid fuel. Boiler and plant modifications represent a modest additional investment when compared to the cost of boilers for solid coal. Environmental impacts are also greatly reduced with coal-water slurries when compared with the use of solid coal. This is a very promising alternative which is already being tested by some utilities in the United States. Once a decision to proceed is made, it would take six to seven years before a new large coal boiler unit can be put into operation. Coal-water slurries can be tested in present PREPA boilers within one year. It is worth noting that some cement plants in Puerto Rico are already switching from oil to coal. We have to do the same thing for the production of electricity.

Technology Transfer: Proposal

As we have seen throughout this paper, Puerto Rico has made significant advances in the development of alternative, renewable energy sources. We are now ready to share these developments with our Caribbean Basin and Latin American neighbors. CEER is in an advantageous position to undertake such a task. In fact, we have already taken some steps in this direction, though mostly in specific projects and sites rather than in general programs of regional scope. One good example of the latter is the project "Development of Alternative Energy Science and

The text should read:

"Engineering in the Caribbean" was carried out by CEER with joint sponsorship from the Association of Caribbean Universities and Research Institutes (UNICK), the U.S. National Science Foundation, the Exxon Education Foundation, and the Caribbean Development Bank. Two workshops have been held under this project--one on wind energy in Barbados and the other on biomass in Puerto Rico. A third workshop, on solar energy, will be held at the University of Florida in Gainesville early next month. A fourth one, on tropical dry forests, is being planned for the Dominican Republic in the fall. More than one hundred persons who are active in various science and technology activities in their respective Caribbean countries will benefit from this project. I am convinced that the time is right to formulate a broad plan to institutionalize science and technology transfer activities in the Caribbean and Latin America. Such a project should be a collaborative undertaking involving the academic and scientific community, the Commonwealth and federal

governments, donor groups and foundations, and the private sector. The institutional setup could be modeled after the East West Center for Cultural and Technical Interchange established in the University of Hawaii under the provisions of P.L. 86-872 of May 14, 1960. The Hawaii center, naturally, has a Pacific orientation and scope. The proposed Puerto Rico center would foster science and technology activities and technical interchanges primarily within the Caribbean Basin but also more broadly within the Western Hemisphere. The UPR Center for Energy and Environment Research has the capability, technical resources and expertise to form a basic nucleus for the operation of the proposed science and technology transfer center. It also has the interest and willingness to contribute its share in the design and planning aspects as well as in the implementation of actual projects and programs. I earnestly hope that this proposal will attract sufficient interest in...

Washington and Puerto Rico to commence serious planning to make it a reality. We at CEER-UPR stand ready to do our part. Concluding Remarks: We expect the energy situation in Puerto Rico to continue without major changes this year. The reduction in oil prices will be a relief for our economy. We are looking forward to the revision of the Energy Policy Plan by the Puerto Rico Office of Energy, to the Report of the Energy Commission of the Puerto Rico Legislature, and to the federal government's Comprehensive Energy Plan for Puerto Rico required by P-L. 96-487. In the meantime, local industries will continue taking steps to reduce their energy costs by using energy more efficiently. Some, like the cement plants, are switching to coal, while others are building their own cogenerating facilities and using other energy alternatives. A study by an energy consultant from California indicates that there are 347 PREPA customers with cogeneration potential.

A change in federal policy would also be very helpful. At the present time, the federal government does not spend money on alternate energy sources which, in its judgment, are ready for commercial operation. An implicit assumption of this policy is that the research and development has been completed and that all investors have to do is build a plant and start making money. However, this assumption does not always hold true. There are many things about new processes which cannot be learned at a desk, in a laboratory, or even in a pilot plant using commercial type equipment. Sometimes substantial learning may continue even with the second and third commercial units. The U.S. National Academy of Sciences in its study "Energy in Puerto Rico's Future" concludes: Puerto Rico, in dealing with its own energy problems, should grasp its opportunity to become an international energy laboratory, focusing on testing solutions especially appropriate to the oil-dependent tropical and subtropical regions of the world. The island's geographical position and its established energy

Research and development facilities enhance this potential, which should be called to the attention of agencies and institutions with investment to make in accelerating developments overseas. In this paper, we have identified alternative energy sources for Puerto Rico such as energy cane, energy grasses, solar thermal systems, solid waste, and FT exploration, all of which are commercially viable and suitable for private investment. This conference should consider how to help bring these development potentials to prospective investors. Also, as already mentioned, there are other energy alternatives that need further research and development. We have ideal conditions to pursue these for the well-being of both Puerto Rico and Caribbean Basin countries. But to do it, the federal assistance that has been reduced must be restored.

A general, broad energy consensus is needed in Puerto Rico so that plans and actions for oil substitution alternatives on a large scale may be implemented as soon as possible. Plans to implement alternative energy sources should be translated into action promptly. If not, in a few years, our people will suffer from our present inaction. Oil is vanishing steadily and continues to be a very politically unstable energy source. Puerto Rico cannot afford to wait or relax until tomorrow. Prudence and economics dictate that we move toward energy self-sufficiency as rapidly as possible.

TABLE 1 POTENTIAL OF RENEWABLE ENERGIES IN PUERTO RICO (COMPARISON OF PROE-NAS-CEER STUDIES)

A. Contribution to Electrical Needs in Percent (%) of Total Electrical Use. Estimates of Puerto Rico Office of Energy (PROE), National Academy of Sciences (NAS), and CEER Studies

Source YEAR 1990, YEAR 2000

Percentage of Annual Production PROE NAS CEER

Biomass 17.2 10.4/3.2 13.8 30/9.9 8.8

Wind 8 8/2 5F 12

Photovoltaics 0.50 - 37 0.7 0.0 0.0

Hydro 1.3 6 28.7

Solar Water Heater Identical 8 2.0/1.1

Industrial

Water Heater 1 3.9/2.3 77 8. Contribution to Non-Electrical in Percent (%) of Total Electrical Use. Estimates from the Puerto Rico Office of Energy (PROE), the National Academy of Sciences (NAS), and CEER Studies Industrial Heat V7.0 2/L17.9* | 15.08 3.8/2.3 15.7% Ethanol 31 1.23. 237 | 20.7/13.4 26.5 1, Maximum potential based on Scott & Garrenstein (Ref. 12). 2. Optimistic/conservative projections based on high energy demand growth assumption. (See Ref. 17) 3, See Iriarte (Ref. 10), includes cogeneration component.

FIGURE 1: TOTAL LEVELIZED GENERATION COSTS OF ALTERNATIVES FOR ELECTRICAL ENERGY PRODUCTION IN PR

E 1985-1990-1998-2000-2005-2010-2018-2020 YEARS

NOTES. | WIND ENERGY ALTERNATIVE ASSUMES NO STORAGE FOR THIS COMPARISON, 2 ALL COSTS ESCALATED 5 1/4% PER YEAR, EXCEPT OIL, AT 9%

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