Proposed Solution for Energy and Environmental Problems in Puerto Rico
Center for Energy and Environment Research
University of Puerto Rico - US Department of Energy
CEER Internal Circulation
University of Puerto Rico Center for Energy and Environment Research
Proposed Solution for Energy and Environmental Problems in Puerto Rico
May 17, 1979

Executive Summary: The Center outlines its proposed solution for the ominous problems of energy and environment which threaten the well-being of the Puerto Rico community. In a national and international context, selected alternative energy sources and concomitant environmental problems are elaborated. Necessary funding and...

The text is analyzed for possible sources. The unique potential of GEER in its ability to exploit the advantages inherent in the Puerto Rico site is included. The possibilities of exporting technology are presented. Relationships with the U.S. Department of Energy, the Commonwealth Energy Office, and the University of Puerto Rico are discussed.

Basic conclusions are:

(1) Puerto Rico's energy crisis demands an expanded role by GEER in R&D which previous levels of funding and institutional relationships cannot sustain.

(2) With adequate funding, GEER can convert the University of Puerto Rico into a technology exporting organization with special relevance to the Caribbean, Latin America, and other areas in the fields of OTE, Biomass, Photovoltaics, ethanol, and solar steam.

(3) The scale of operations and funding level of GEER are not adequate for performing the research and development role in Puerto Rico's energy crisis.

(4) No alternative institution of equal capacity for such a role is perceived to exist in Puerto Rico.

(5) Without adequate support for R&D, the energy crisis will reach disastrous proportions.

Recommendations are:

(1) The appropriately redefined role in R&D should be assigned to the Center and necessary funds should be provided.

(2) GEER should remain as a unit within the UPR but be allowed to retain its innovative practices.

(3) Ties with the Office of Energy should be strengthened, and

(4) Proposed legislation on funding should receive the endorsement of the President.

INTRODUCTION AND BACKGROUND:

Reorganization in the Federal government since the founding of the Puerto Rico Nuclear Center (PRNC) under the Atomic Energy Commission (AEC) in 1956 has resulted in the establishment of the Center for Energy and Environment Research (CEER) with a new mission and funding structure. The move in 1975 to start the process of making the Center self-sustaining and competitive necessitated the adoption of new strategies for conducting research and finding new funding sources. In these efforts, CEER has been quite successful.

Examination of progress toward self-sufficiency has revealed important implications for the long-term success of the Center. In planning now for the future programs and funding for the Center, considerations must be given not only to assuring continuity and development of the Center, but more importantly to its ability in solving the pressing problems of energy and environment with which Puerto Rico and the whole nation are confronted. The problems in Puerto Rico are great and will require an investment of resources which may not have been considered possible five years ago. The objectives of this document are (1) to present an assessment of the Center's progress toward becoming a self-sustaining and competitive instrument for energy and environmental research in Puerto Rico, (2) to study various institutional frameworks within which the Center could achieve its objectives, (3) to analyze the trajectories which are likely to follow from alternative funding scenarios and (4) to recommend an institutional framework and a strategy for seeking funding which are most appropriate for achieving CEER's short and long run objectives.

THE PRESENT SITUATION AT THE CENTER

The Center counts as its principal resources forty-three scientists with an established reputation for productivity and responsiveness to the Department of Energy (DOE) needs especially in the areas of tropical ecology, nuclear research, education and more recently in alternative energy source development. The research facilities valued at $12 million are the best in the Caribbean and the FY 1979 budget amounts to approximately 3.5 million dollars of which about 2.2 million represent base funding. The Center has been more successful than expected in securing funding from competitive sources during the first three years of the transition period (having secured $900,000, compared to a predicted $150,000 in FY 1978).

A. Prospects for the Continued Development of CEER After September 30, 1981.

When in 1976 it was decided that the Center

The transition should begin from a DOE contract facility to integration within the University of Puerto Rico. The budget was $2,706,000, of which $1,230,000 is “base” money for training and education. $294,000 was from competitive grants and the remainder was in BER. The decline in base support from DOE may be noted. This is particularly important in light of the fact that the UPR has not provided substitute funds, and the difficult resource management problem faced by the University Administration. There are regrets regarding the circumstances in which the UPR's commitment has not been fulfilled.

This lack of support has not been fulfilled in accordance with the provisions of the DOE (EEDA) action memorandum of April 16, 1976. Faced with the prospect of declining base support and with it the resources to adequately pursue new sources of funding, a decline is foreseen in the ability of the Center to respond to Puerto Rico's needs as it has been in the past.

II. FUTURE PROJECTIONS

A. Revised Mission

The new mission of CHER is to address energy and environmental questions that arise for the industrialized, tropical island of Puerto Rico. It aims to do so in a way that has maximum applicability to other areas. Puerto Rico needs expert information to guide planners in the orderly development of the island. Orderly development requires the objective assessment of energy alternatives in the context of their environmental and economic costs. CHER is the only institution on the Island with the appropriate orientation, tradition, independence, reputation, and expertise to perform this necessary task.

B. Competitive Funding Prospects

While DOE funding of relevant research is expected to continue, it will become a smaller fraction of the total program needs. However, it is unrealistic to expect that the observed rate of increase of competitive funding can be sustained. There is a need for research in other areas.

Research to Secure Environmentally Acceptable Energy, Alternative Vigorous efforts will be required to solve the special energy and environmental problems for Puerto Rico. GEER is already involved in programs having the appropriate orientation, but much more work will be needed to solve the problem. Several cases may be cited as examples of the relevance and cost-effectiveness of GEER's present and planned R & D programs which have relevance for the Commonwealth. OTEC, photovoltaic, biomass, ethanol, and solar steam are under consideration as alternative energy sources for Puerto Rico. More detailed information regarding the R & D scenarios for these may be found in Appendix D.

'Any sort of reasoned approach towards energy independence. CHER is the only agent on the Island capable of and already involved in such work for Puerto Rico and CRER will not, without assurances of base funding, be able to continue this leadership role. The summary of the examples scenarios considered, under crash type R & D Program heavily involving CEER, is given in Tables 2 to 6. Table 2 includes an estimate of the energy requirements in Puerto Rico for the period 1976 through 2000. It is assumed that the present socio-economic structure persists and that no R & D program in search of energy alternatives is functioning. The fuel bill for Puerto Rico during the FY 1979 exceeds one billion dollars and the total bill for the rest of the century is estimated at approximately 156 billion dollars. (2) (@) Column 6, Table 1.

TABLE 2 ESTIMATES OF PUERTO RICO'S ENERGY REQUIREMENTS TO THE YEAR 2000 UNDER PRESENT SOCIO-ECONOMIC STRUCTURES AND ABSENCE OF STRONG R AND D PROGRAM ON ALTERNATE ENERGY SOURCES

"Million Barrels of Oil Imports for Estimated"

Year	Electricity (1)	Gasoline (2)	Industry(3)	Total Import	Total Cost ($ millions)
1976	21.7	17.6	26.3	1377	215
1978	24.5	16.5	23	3973	T2705
1980	27.5	17.3	263	16.78	1203
1982	29.7	13.0	29.1	21.307	1704
1984	33.6	13.8	30.5	25.007	2055
1986	35.3	32.0	28.55	36.29	3390
1988	38.9	---	---	44.72	4633
1990	42.9	---	---	55.00	6266
1992	47.3	---	---	62.75	7856
1994	51.8	---	---	71.50	3796
1996	56.5	---	---	81.25	70928
1998	63.4	---	---	92.50	14793
2000	69.1	---	---	103.75	718016
Total	---	---	---	---	$155,029

(1) Statistical Correlations between population and GNP and between GNP and Electrical Energy Generation. Correlation 0.998. See Appendix x

(2) Gasoline Consumption growth projected conservatively between 2

1/2 - 3% per year vs. 6.6% actual. More accurate predictions to be included in CHER Energy Studies.

(3) Industrial needs projected at 5% per year growth. More accurate predictions to be included in CHER Energy Studies.

(4) Fuel of process escalation indicated is approximately 1980-85: 14.32/years; 1985-90: 11% per year; 1990-95: 6.8% per year; and 1995-2000: 6% per year.

Table 34 presents an illustrative program of energy alternative objectives under a very tight schedule which will only be achieved by a concentrated and coordinated effort between the various government energy planning related organizations and in which GEER is the main R&D researcher. The contents of the table phase the amounts of power in electricity, steam, etc., which could be achieved in the period indicated.

'Table 3B indicates the amount of oil saved by the proposed crash program by the indicated scenarios.

'Table 4 illustrates the potential contribution of the proposed energy alternatives scenarios to the total fuel oil consumption of Puerto Rico. A reduction of nearly $52 billion, equivalent to 36% of the total dollar expenditures up to the year 2000 is indicated. This large amount is probably the maximum saving which could be achieved since it is predicated upon a very tight schedule and R & D crash programs requiring inter-agency coordination and cooperation.

Table 5 illustrates a possible source of revenues to finance the R & D program. A fuel tax for energy and environment research and development is proposed on all non-renewable fuels consumption in Puerto Rico. The tax proposed is based on BTU consumption and it fluctuates between 1.5¢ to 2.5¢ per million BTU. A gallon of gasoline contains some 140,000 BTU, therefore, this would hardly add 0.2-0.35 cents to a gallon of gasoline. A draft of such proposed legislation is included as Appendix B.

Table 38 SCHEDULE OF PROPOSED SCENARIO PROGRAM OBJECTIVES.

I'm sorry, but the text appears to contain random characters and numbers which are not forming any coherent sentences or data. It might be corrupted or incorrectly inputted. Could you please provide more context or the correct information?

The last two columns of the tables indicate the suggested source of funding. Column 13, labeled “Base Funding Requirements” in Table 6, is the minimum projected funding requirements for CEER. If the proposed example scenarios or any other similar type program is not undertaken, CEER still needs to be funded to the level shown in the indicated column. This is discussed more fully in the section below. An adequate attempt to solve the energy problems of Puerto Rico will require that during the period 1980 to 1990 a total of approximately $199 million (3) be made available. This represents an average investment in R & D for energy and environment in the vicinity of $18 million annually.

ALTERNATIVE INSTITUTIONAL FRAMEWORKS

Faced with the problem of continuity and growth, the Center has considered the means of assuring both. The alternatives are dealt with briefly below. More extensive versions are contained in the Appendices.

A. Continue within the existing organizational structure of UPR and extend the present relationship with DOE. DOE is well aware of the capabilities of CEER and is likely to approve some continuing relationship.

Pro 1: The UPR is likely to continue to look favorably upon CEER activities and give it wholehearted support.

Pro 2: Continuity will not require any adjustment to the new perspective which might be required if a new sponsor or organizational location results. Levels of funding will not approach the amounts required in an adequate program as outlined above. Increases in funding from UPR are not likely to be forthcoming given the percentage commitment which has been realized in the past. This alternative will not provide the dynamic organization and response which Puerto Rico's energy and energy research problems demand.

B. Integration with the Puerto Rico Office of Energy to form a state.

Pro 1: A total integrated approach to the problems of energy would result.

Pro 2: More efficient utilization of resources.

"Night can be achieved. Possible sponsors or funding might be attracted by the combined efforts. The executive branch of government is not supportive of research activities. "Operational" and "Service" considerations usually outweigh research needs. Full integration within the public service might rigidify the organization and might lessen the responsiveness and flexibility which have characterized it until now.

A new Department of Energy would suffer the normal growth and development problems in a new bureaucratic structure. How long it would take to get beyond its own problems of organization to those of energy and environment is an open question.

Establishing an Independent Private Entity

Setting up a completely independent private organization might prove attractive to some but the divorce from the University would be against the philosophy of the Center which perceives its role as a member of the University community. Bonds with the UPR system do not prevent the Center from facilitating work with private universities. At present, such activity is an ongoing part of the functioning of the Center.

Modifying Present Arrangements with UPR

It is obvious that CEBR is well able to function as an autonomous research institution. Perhaps then, the idea of it being a wholly detached, essentially private institution should be explored. This exploration could take into account the histories of the Michigan Engineering Research Institute, Southwest Research Institute (University of Texas), Jet Propulsion Labs (Cal Tech), and counterparts at Harvard, Stanford, and Carnegie Mellon. While still closely related to their respective university systems, these organizations operate as integral corporate structures. Control is still exercised by the University through representation on the Board of Directors, but day-to-day management and finance

functions are carried out by the administrators of the research institution. Objections to this arrangement can be expected."

Resistance might be overcome by paying dividends on stocks or interest on bonds to the University and by a contractual agreement to provide limited free research assistance and facilities. The advantage to the University would be an immediate reduction in operating costs, and if CEFR were successful, there would be the potential for good income from both Government and private funding.

FUNDING ALTERNATIVES - THE BASIC PROBLEMS
Legislative Appropriation

Various alternatives for CEER funding were investigated and discussed by the staff. They included:

(a) Extension of the DOE contract. Good prospects exist for negotiating a new contract with DOE, but it was the general consensus of the staff that the level of funding will not be close to that desired for adequate basic funding.

(b) The probability of increasing the UPR budget to the levels of $518 million annually. This alternative was given a very low probability of success.

(c) Request to the Legislature to allocate to CEER part of Puerto Rico Water Resources Authority (PRWRA) contribution in lieu of taxes. Law 83 of May 2, 1941 requires PRWRA to contribute a percentage of its gross revenues to the State General Fund. However, recent amendments have fully committed this contribution in relation to the fuel adjustment clause subsidy given to consumers with less than 400 kWh monthly. This alternative was discarded.

(d) Request to the Legislature for fixed yearly allocations in the level of $5-18 million (The Rum Pilot Plant legislative fund allocations history was reviewed). Due to the present tight government budgetary conditions, a low probability of success was assigned to this alternative.

(e) The enactment of a new bill imposing a tax of 1.5-2.5 cents per million BTU on all imported fuels consumed or sold in Puerto Rico to finance CEER programs. This is considered the most logical alternative.

CONCLUSIONS

1. Puerto Rico's energy crisis demands an expanded role by CEER in R&D which previous

Levels of funding and institutional relationships cannot sustain. With adequate funding, CHER can transform the University of Puerto Rico into a technology exporting organization with special relevance to the Caribbean, Latin America, and other areas in the fields of OTEC, Biomass, Photovoltaics, Ethanol, and Solar Steam. The scale of operations and funding level until now were adequate for transition from the Puerto Rico Nuclear Center to the founding of CEER. However, they are not adequate for performing the research and development role in Puerto Rico's energy crisis.

4. No alternative institution of equal capacity for such a role is perceived to exist in Puerto Rico. Without adequate support for R&D, the energy crisis will reach disastrous proportions.

RECOMMENDATIONS:

1. It is recommended that the appropriately redefined role in R&D be assigned to the Center and that necessary funds be provided.

2. CHER should remain as a unit within the UPR system, but be permitted to retain its innovative practices.

3. Ties with the Office of Energy should be strengthened.

4. The proposed legislation on funding should receive the endorsement of the President.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX A - MISCELLANEOUS FUNDING SOURCES

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH - UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX A - MISCELLANEOUS FUNDING SOURCES PATENTS

Towards the generation of funds, it is recommended that a concerted effort be dedicated to the development of Center policy relevant to the licensing of patents in energy and environment. If necessary, the policy could extend to all units in the UPR System with the obvious benefits which would accrue from inventions resulting from the projects financed by the UPR and CHER within it. Because there are potential patents in ongoing work, it is suggested that the patent study begin as soon as possible in order that the economic benefits may be promptly realized.

PUBLICATIONS AND DATA

SERVICES As a further revenue generator, it is recommended that the possibility of establishing a Publications and Information Division be explored. Offerings for public sale would include topics in Education, Research and Service in the fields of Energy and Environment. The publications would be available in Spanish and English with selected items in Portuguese and French. In addition to publications, a service could be offered in providing base data in Energy and Environment to interested parties. In the past, data related to solar applications has been requested by domestic and foreign corporations holding contracts with private industry or government agencies. Direct and diffuse radiation data collected in our measuring stations has been requested and provided without charge. The companies using the data charge their clients for this service. It would seem reasonable that a policy for recovering costs to the Center could be implemented. In similar fashion, it would be possible to recover the cost of publications such as those pertaining to solar applications for domestic solar heaters from which there is an obvious benefit to the consumer.

INDUSTRIAL LIAISON PROGRAM

As part of its design for continuity and development, CEER has established an Industrial Liaison Office. The function of this office is to provide essential services to industry in supplying information to prepare reports on the state-of-the-art in pertinent fields, organizing conferences and symposia, and various other services. Interaction between industry and the University, long discussed but short on actual exchange of meaning between the two, promises soon to be a reality. An analysis of counterpart activities at leading Universities on the mainland suggests that the Massachusetts Institute of Technology (MIT) Model is the most appropriate. Discussions have already taken place with MIT and CEER personnel participating. No relevant obstacles are anticipated in putting the program into operation. Revenue generated by the program will...

"Lessen the financial burden of the Center.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX 5

PROPOSED LEGISLATION

(CENTER FOR ENERGY AND ENVIRONMENT RESEARCH UNIVERSITY OF PUERTO RICO)

8 April 1979

APPENDIX 8

A BILL FOR APPROPRIATING FUNDS FOR THE CENTER FOR ENERGY AND ENVIRONMENT RESEARCH UNIVERSITY OF PUERTO RICO

STATEMENT OF MOTIVES

The Center for Energy and Environment Research of the University of Puerto Rico is an institution dedicated to the study and development of new energy resources such as the sun, wind, and sea, while also exploring the potentials inherent in recycling, conversion, or elimination of the waste products and pollutants of modern society.

Among its current projects are the development of solar photovoltaics, ocean thermal energy conversion, use of sugar cane hybrids as biomass fuel, bilharzia control, effects of industrial developments and population growth on land masses, etc.

The Center's principal objectives:

1. To serve as the focal point for energy research in Puerto Rico, in order to achieve energy independence.

2. To help Puerto Rico develop the scientific engineering and other trained personnel needed for the future in the energy environmental and related fields.

3. To continue research and training programs in environmental sciences and technologies.

The Center for Energy and Environment Research of the University of Puerto Rico, evolved from the Puerto Rico Nuclear Center, established by the U.S. Atomic Energy Commission in 1957. The Nuclear Center was operated by the University of Puerto Rico for the Commission until the agency was superseded by the U.S. Energy Research and Development Administration (ERDA) in 1975.

The Nuclear Center trained more than 2,000 students in nuclear sciences, engineering, and medicine. Now the Department of Energy is funding CEER through a contract with the University of Puerto Rico. This evolution has given CEER the required expertise and modern available facilities. At present the"

CEER is currently studying or developing more than forty (40) principal projects related to energy conversion and conservation. The ongoing energy crisis, which is caused by a global energy shortage, is expected to worsen throughout the remainder of this century. Puerto Rico, with its total dependence on imported fossil fuel for energy, is particularly vulnerable to disruptions in the global energy market. This is an unusual situation, as there are few places in the world so generously endowed with natural energy: solar radiation, ocean temperature differential, wind, waves, and currents, all potential non-polluting power sources. CEER has been conducting some projects in this regard, using funds initially allocated by the ERDA and now by the Department of Energy. They utilize currently available facilities, which are valued at approximately twelve million dollars ($12,000,000). The Department of Energy (DOE) is transferring these facilities to the University of Puerto Rico. CEER has been operated by U.P.R. under a contract with DOE, which funds all operational costs while also allocating additional money grants for individual projects on a competitive basis. These projects aim to develop energy from natural resources and protect the environment.

On September 30, 1981, the contract expires, and thereafter, DOE will no longer cover the operational costs of the CEER. Although the funds obtained from grants on a competitive basis will continue, they will not be enough to cover all expenses. It is therefore necessary for the Legislature to appropriate the necessary funds to cover CEER's operational needs in order to continue the development of new energy resources, which will fulfill an urgent need for the people of Puerto

Rico. For this purpose, it is enacted by the Legislature of Puerto Rico that it is hereby found and declared that the purposes of the Center for Energy and Environment Research (CEER) of the University of Puerto Rico are for development.

The text should be corrected as follows:

The development of environmentally acceptable energy alternatives through research on new fuels to substitute for those made from petroleum, and research to understand and protect the ecology and natural resources of the Island, are public purposes in all respects for the benefit of the Commonwealth of Puerto Rico. The programs that have already started should continue, and new projects and grants should be sought to perform research and development. This is necessary, and thus it is essential for the Legislature to appropriate the required funds to continue the same. The sum to be appropriated every year will be obtained by levying taxes on all types of fuels, crude, refined or combination of both, that enter the Commonwealth of Puerto Rico as specified here.

Taxes to be levied will be equal to one and a half cents ($0.015) per million BTU's (British Thermal Units) of calorific value for the first two fiscal years (1980-81; 1981-82); two cents ($0.020) for the next two fiscal years (1982-83; 1983-84); and two and a half cents ($0.025) for each fiscal year thereafter. The Secretary of the Treasury of the Commonwealth of Puerto Rico is authorized and directed to collect the mentioned taxes and to place the funds therein collected at the disposal of the Director of the CHER starting July 1, 1981. All laws or parts of laws in conflict with this are hereby repealed. This Act will take effect ninety (90) days after its approval.

[ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO]

APPENDIX C: INNOVATIONAL ORGANIZATIONAL STRUCTURE WITHIN UNIVERSITY OF PUERTO RICO (CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, UNIVERSITY OF PUERTO RICO, 8 April 1979)

APPENDIX C: THE POSSIBILITIES OF ESTABLISHING AN INDEPENDENT RESEARCH CENTER INTEGRATED WITH THE UNIVERSITY SYSTEM

Given both the history of CHER and its current mode of operations, it is clear that it could, and does in fact, operate as a relatively autonomous arm of the University of Puerto Rico.

While subject to general university policies and reporting directly to the Office of the President, its routine activities and its relationships with other institutions are determined by the Director and implemented by the in-house staff. Under these conditions, it is worth considering the further benefits which would accrue to the UPR and the increased flexibility which CHER would develop if it were to be operated as a quasi-independent Research and Development Center under a new corporate structure. This development would parallel the histories of some well-known institutions such as Arthur D. Little (Harvard), Southwest Research (University of Texas), Jet Propulsion Labs-JPL (Cal Tech), and many others which are lesser known. These organizations had their inception as "Think Tanks" or specialized university research laboratories during World War II as specifically funded operations and then evolved into independent research institutions as their expertise and experience broadened and became more generally available, while still closely related to their respective university systems. Under their independently operating corporate structure, their flexibility, responsiveness, and competitiveness have not only eliminated the financial obligation of the University to support them, but have also proven to be a valuable source of non-legislated funds for the University as well. Because of its equity position and the resultant representation on the Institution's Board of Directors, the University still has a voice in the policy and operation of the institution.

GENERAL CONSIDERATIONS

Implementation Procedures

Preparation of preliminary proposal and time schedule by CEER. Establishment of UPR/CEER Liaison work committee to draft necessary legal/University and administration steps. Stepwise authorization by President, University Board, CHE as required. Establishment of non-profit corporate legal structure. Organizing of Board of Directors. Establishment of CEER administration. Arrange transfer or long term.

Lease of CHER facilities for UPR to CEER for UPR equity. Establish CEER-UPR financial relationship. Establish CEER-UPR scientific relationship. Implementation Requisites: 1. GEER base funding sufficient for 5-10 year minimum operating level. CHER competitive funding growing at established rate. UPR willing to develop this relationship. All legal and university regulations allow implementation or can be modified to fit the situation.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO: Summary

[APPENDIX D EXAMPLES OF ALTERNATIVE SCENARIOS IN ‘ENERGY AND ENVIRONMENT]

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

7 April 1979

THE ENERGY PROBLEM IN PUERTO RICO:

Various efforts are being undertaken by a variety of organizations in the Puerto Rico Government in pursuit of solutions to energy and environmental problems which are adversely affecting Puerto Rico and its general economic welfare. Every effort tends to provide some degree of assistance to the solution of the energy problem. As the Director of the Office of Energy has said, the final solution does not lie under one option but in the sum of many options taken together. The efforts of energy conservation, for example, should not be underestimated, as well as other programs now under consideration. The seriousness of the energy crisis is now looming more closely and threatening the Puerto Rican livelihood, economics, health and every sector of the lifeblood of the present civilization as we know it in the Western world. It is, therefore, felt that an outlook with an aggressive energy program with definite goals and objectives should be developed and pursued to bring forth solutions in the shortest time possible but with known and calculated acceptable risks. CHER studies on the economy of Puerto Rico and the dynamics of population growth predict that in order to maintain nearly the same level of economic welfare, the electrical energy generation for the year 2000 will be three times the electrical

According to sources, the fuel bill for Puerto Rico in 1979 exceeded one billion dollars. The total bill for the rest of the century is estimated at 155.829 billion dollars. Table 3A presents an example of a program for energy alternative objectives. This program follows a very tight schedule and is only achievable through concentrated and coordinated efforts between various government energy planning organizations. CEER is the main R&D researcher in this program.

Table 3B indicates the barrels of oil saved by the proposed crash program example scenario. Table 4 illustrates the effect of the example energy alternative scenarios proposed on the total fuel oil consumption of Puerto Rico. A reduction of nearly 52,000 million dollars is expected.

Table 2 provides estimates of Puerto Rico's energy requirements up to the year 2000 under current socio-economic structures and without a strong R&D program on alternate energy sources.

The table lists the million barrels of oil imported for each year, broken down by electricity, gasoline, and industry sectors. It also provides the total annual cost of energy. For example, in 1976, 21.7 million barrels were used for electricity, 17.6 for gasoline, and 26.3 for the industry, for a total of 64.7 million barrels. The total cost of energy for that year was 14.70.

The table continues with this data up to the year 2000, with the total cost of energy reaching 102.6 and the total number of barrels reaching 175.6 million. The total cost for the period is $155,829.

The table notes statistical correlations between population and the numbers provided. The details of these correlations are not provided in the text.

The text seems to be a mix of coherent sentences, data, and gibberish. Here's an attempt to fix it but note that some parts are uninterpretable:

"GP and between GNP and Electrical Energy Generation. The correlation is 99%. See Appendix F. (2) Growth in Gasoline Consumption is conservatively projected between 2 1/2 - 3% per year vs. 6.6% actual. More accurate predictions to be included in CEER Energy Studies. (3) Industrial needs are projected at a 5% per year growth. More accurate predictions to be included in CEER Energy Studies. (4) Fuel oil process escalation indicated is approximately 1980-85: 14.32 /year; 1985-90: X% /year; 1990-95: 6.8%/year and 1995-2000: 6x% /year.

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Table & Potential Energy. Cost reductions per example scenarios - (6) RSTO. Reduction RL Fraction Te) Million Barrels OTE 30° pais Dollars (of scenarios) \year [10 Savings ‘Savings ‘Savings of scenarios in scenarios| with scenarios | Total-wow Scenarios.

s905_| 99.9 0.53 17.32 0.58,
906| 93.4 364 204-67,
ee 3987| 96.9, 70:94 40
Te 1988| 103.6. 18.07 208
a 1969| “108.6. 23.40 Tr 60- 2
1990| “113.9, 33.77 1857 38
iea1_|_119.9, 33.77 11984 28
i992| 125.2 33.77 Bets aie
3993 [190-8 20:50, ERIC 238
1994| 137.0 44217, 3158 328
1995| 142-8. 52.88 aoa ae
1996| 148.9 0:04 42868 408
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lrorars| 2072.6 657.18 51,909.0 368 loose 108.

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Unfortunately, due to the nature of the text, it is difficult to correct it completely. It seems to be a mixture of miscopied data and uninterpretable sentences.

Break - 362 of the total dollar expenditures up to the year 2000 were accomplished by the example scenarios. This high figure is probably the maximum saving that could be achieved since it is predicated under a very tight schedule and a crash R & D program requiring interagency coordination and cooperation. Table 5 illustrates a possible source of revenues to finance the R&D program. A fuel tax for energy and environmental research and development is proposed on all non-renewable fuel consumption in Puerto Rico. The proposed tax is based on BTU consumption and fluctuates between 1.5¢ to 2.5¢ per million BTU. A gallon of gasoline contains around 140,000 BTU, therefore, this would hardly add 0.2 ~ 0.35 cents to a gallon of gasoline. Table 6 illustrates the total CEER fund requirements for the example scenarios. The last two columns of Table 6 indicate the suggested source of funding.

Year | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000

The logic in selecting and setting the example scenarios has been based on the information, experience, and knowledge generated from R&D programs undertaken by CEER since 1976. The level of effort has been very low, at the rate of 2-3 million dollars per year, 100% funded by the

Federal Department of Energy. This low level of effort needs to be increased considerably as indicated in order to produce meaningful results. Economic considerations and evaluations, potential capacity of the alternatives to meet local energy needs, and actual technical status and projections of the alternatives were taken into consideration. These can be summarized as follows: OTEC (Ocean Thermal Energy Conversion) makes use of the temperature differential between deep sea waters (3000 ft) and surface water to generate

Electricity. This concept has the potential to generate all the energy needs of Puerto Rico at some future date. Ocean-based or floating type of plants in the southern Caribbean sea will have practically no impact on land utilization resources. It is estimated that an OTEC-10 (40 MW plant) concept could be operational within 4 years. Preliminary economic calculations under certain assumptions indicate PRURA could afford $26.2 million dollars towards investment and the energy obtainable will be comparable in cost to one 450 MW coal plant located at Rincon with Flue Gas Desulfurization. It is suggested that the Puerto Rico Government contributes the same funds for research and development. The project is estimated to cost $300 million including escalation and interest during construction. The Federal Government appropriation requirement is $247.6 million. A risk analysis consideration indicates an acceptable calculated risk for public corporations. Cost calculations were performed for a 250 MW OTEC concept operational by the year 1990-91 and it is shown to be 61% of the 450 MW coal plant cost of electricity. From this, it is assumed that PRRA can then finance completely such concepts from there on. Such an aggressive approach will definitely win the OTEC-10 concept for Puerto Rico over the Gulf States and Hawaii competition. OBER requested R&D funding is indicated.

PHOTOVOLTAICS - Photovoltaic systems produce electricity by converting direct solar radiation into electricity using photoelectric cells. A large fraction of the energy is stored for use during non-daylight time. It is a completely static system with no known adverse environmental effects. The concept has enough potential to generate all the electric energy needs of Puerto Rico required by the year 2000 but it will require 90,000 - 100,000 acres of land - enormous farms of solar collector cells and electronics. The objectives for photovoltaic systems are defined in the program, its economics in the Puerto Rico scenario assessed, and

The R&D funds requirements are scheduled. The most ambitious objective in the program is to have an industrial park with cogeneration (steam for industries plus electricity) of 250,000 KV capacity for the early 1990s. CER's experience on a small similar project being planned at present is of paramount importance for the undertaking of this major task.

The economics of the project indicate that the energy costs will be 48% of the cost of a 450 MW coal plant, without the steam cogeneration portion. When the steam portion is added, the economic attractiveness is even higher. These costs were determined for the P.R. scenario by using higher costs than the most recent basic data cost information.

R&D funds need to be secured by CEER from the Puerto Rico Government for this project at the level of $40 million, excluding advance. It is assumed that the Federal Government will match these funds concept development for a total of $80 million requirements in R&D. A consortium of private enterprises, PRNRA and Fuente is suggested for the capital investment.

Biomass is practically an agricultural enterprise. It consists of planting selected optimized species for mass production, harvesting, solar drying, storage, transportation and burning the biomass in a suitably designed boiler to produce steam to run the turbo generators that produce the electricity. As such, an electric plant fueled with biomass is not very different from a conventional fossil fuel fired power plant. Biomass alone can supply all the energy needs of Puerto Rico by the year 2000, but it will require 700,000-800,000 acres of land. One single 450 MW plant in operation by the year 1987, operating at 75% capacity factor, could supply 13% of the electrical energy needs. Approximately 55,000-60,000 acres of land will be required to feed the plant.

Solar Electricity and Economic Approach to Solar Energy - Wolfgang Beles and Beate Hurbhe Power Program, Commission of European Community.

The principal and immediate

The objective of a biomass program is to convert an existing sugar mill to handle 1000 tons of biomass per day and determine the logistics, production, burning efficiency, transportation, etc. The size is equivalent to a 62,500 kV electrical boiler and is large enough for extrapolation to 400-500 Mi boilers. The economic analysis indicates that biomass is the costliest of the three alternatives, but still has a good economic advantage over the coal alternative. Preliminary calculations indicate that the cost of electricity from biomass is 86% of the cost of electricity from a 450 Mi coal plant. In its favor, is the fact that this alternative will require the least expenditure of funds in R&D. Technologically, it is the least risky of all three considered but is, of course, the most costly. The principal objective is to develop the necessary data so that PRIRA can, within 1-2 years, incorporate in its steam boiler bid specifications, enough data for specifying boilers to burn any of three fuels - oil, coal, or biomass, and have all the logistics developed to burn biomass by the year 1986-87.

ETHANOL (MOTOR FUELS) - Ethanol can substitute gasoline or can be blended with gasoline to form a mixture as gasohol. Gasoline with 10% ethanol can be burned in motor vehicles without carburetor modifications. For mixtures greater than 10% ethanol, carburetor modifications are required. The consumption of gasoline in Puerto Rico during the last fiscal year was 658 million gallons. Consumption has been increasing at the rate of 6.62% per year during the last 12 years. The gasoline requirements of Puerto Rico for the year 1990 (assuming the growth rate is halved) is conservatively estimated to be one billion gallons of gasoline (equivalent to 1.67 billion gallons of ethanol). This could be met with plants produced with a program requiring 1,000,000 acres of land, which is approximately 83% of the agricultural land in Puerto Rico. Costs are estimated to be competitive. The R&D program objectives include the modification.

The text should be corrected as follows:

The sugar mill aims to process 4000 tons of green sugar cane per day to produce approximately 6000 gallons per day of ethanol. The experience is then extrapolated to a larger industrial scale to produce 12% of the gas requirements by the year 1990. These objectives are based on the approval of planned pilot plant operations at the UPR-RIM Experimental Station this year, and the existing programs for the development of Saccharum hybrid species for increased yields. The total R&D funds required are estimated at 12-13 million, excluding advanced concept developments.

SOLAR STEAM: CEER has developed a highly efficient and inexpensive solar concentrator for producing industrial steam. A project is underway with Bacardi Distillers to produce solar steam at the Bacardi Rum Plant in Toa Baja (Palo Seco). The production of ethanol, as well as many other industrial processes, requires large amounts of steam. The production of 11% of the gasoline requirements for the year 1990 in ethanol will require approximately 1 million pounds of steam per day.

The program objective is to reduce the cost of ethanol (and at least 40% of the steam energy requirements) by supplying the requirements of the ethanol project previously described with solar energy. This will further enhance additional industrial uses of the technology. It is estimated that the R&D funding requirements for this project is $25 million, excluding the development of advanced concepts and related material development.

Total Budget: The total R&D budget required by CEER from the Puerto Rico Government to aggressively tackle all alternatives is indicated in Table 6, entitled "Summary Table of Total CEER Funding Requirements for Example Scenarios". The details and rationale of the proposed program are contained in the technical analysis which follows.

APPENDIX D: TECHNICAL ANALYSIS OF ALTERNATIVE ENERGY SCENARIOS

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ANALYSIS OF EXAMPLES OF POSSIBLE SCENARIOS IN ENERGY AND ENVIRONMENT - OTEC

A. Program Objectives

1. Demonstration Plant in Operation by the year 1984-85. A 40 MW plant should be planned so that extrapolation to at least a 5-fold increase in capacity can be achieved.

The scale could be attempted in a second-generation plant (10 MW modules as per OTEC-10, DOE Program). This plant could generate about 1.12% of Puerto Rico's energy needs by 1985.

2. Large Commercial Plant in Operation by the year 1990: A 250 MW plant can be planned as an extrapolation of the Demonstration Plant. The Demonstration Plant along with this plant can generate 7% of Puerto Rico's energy needs by the year 1990.

3. Electrical System Addition on a Competitive Basis: The first 500 MW OTEC Plant in operation by

the year 1995 and additional 500 MW OTEC units in the years 1977, 78, and 79. All the OTEC units could be generating the equivalent of 17.5% of the electrical energy requirements of the year 1999.

B. OTEC Economics in Puerto Rico Scenarios: A 40 MW Demo Plant is estimated to cost about $5,000 per MW in 1978 dollars. The estimated cost of energy can be roughly figured as follows:

Investment charges:

a. Project Investment - $200,000,000 (60,000 MW) (5,000 MW)

b. Yearly Investment charges at 10% cost of money - $ 20,000,000

c. Yearly energy production at 85% capacity factor - 298 x 10 kwh

d. Investment charges in mille/kWh - 67.1 mills/kWh

Operation and Maintenance (O&M): The O&M cost of an OTEC Plant cannot be too far off the costs of an equivalent oil plant. The marine portion, such as hull and exposed seawater parts, will require more maintenance, but these parts could probably be taken care of in a larger time cycle than the routine yearly maintenance. This could probably be accomplished by moving the plant to special shipyard facilities.

Assuming that the single OTEC plant will require the same amount of manpower as the two (450 MW each) fueled Aguirre Units, this would amount to approximately a staff of 170 men. At an average salary of $24,000 per man, (PREPA average salary for power plants) the total staff salary would be:

Total Staff:

The corrected text is as follows:

The salary is 170 x 24,000 which equals $4,080,000. The ratio for a coal plant, which is a more complex operation, between total staff operation cost including Flue Gas Desulfurization costs, has been determined by CEER Studies to be 2.33. Using the same ratio, the total O&M (Operation and Maintenance) is calculated as 2.33 x $4,080,000 which equals $9,506,000. The O&M costs in mills/kWh are 31.9.

Fuel costs are estimated to be zero. The total cost for the Demonstration Project is 99.0 mills/kWh in 1978 dollars. The total levelized cost for 1985 can be estimated by including escalation and interest during construction and leveling the O&M cost during the plant's lifetime.

Assuming a 7% escalation per year, one year planning and contracting period, 2 years design and 3 years construction, the interest during construction and escalation factors can be calculated as follows:

- Escalation before construction = 1.07^3
- Escalation during construction = (1.07)^5
- Interest during construction = 0.07 x 5

The total factor for escalation and interest during construction is then 15. Operation Escalation at 7% per year between 1979 and 1985 equals 1. The levelizing factor for a 35 year lifetime at a 10% cost of money in a stable inflationary economy yields a levelizing factor of 1.75.

The total levelized cost for 1985 is calculated as follows:

- Investment charge = 1 x 0.5
- Operation and maintenance = 31.9 x 1.5 x 1.75

The total levelized cost for an OTEC Plant is 184.3 mills/kWh.

For escalation and interest during construction considerations as well as levelizing considerations, cost of money, etc, see separate CEER studies (Base line costs of commercially available energy alternatives in P. R. scenarios).

The above cost can be compared with 92.54 mills/kWh for a single 450 MW coal plant at Rincon with flue gas.

Desulfurization has a lifespan of 35 years and operates at a 75% capacity factor. This lower capacity factor is justified in an economic dispatch competition. If the investment charge of the OTEC plant were 8.8 mills/kWh, the coal plant and the OTEC plant will have the same energy production costs of 92.5 mills/kWh (total levelized cost during plant life). At 8.8 mills/kWh, the total yearly investment charge will be $2.62 million (85% plant capacity factor), which justifies an investment of $26.2 million in terms of 1985 dollars for PRIRA (or $17.4 million in terms of 1978-79 dollars). If the local government matches these PRIRA funds for the R&D and infrastructure requirements for a total contribution of $52.5 million dollars (1985 dollars) from Puerto Rico, the Federal Government contribution to be sought is $267.5 million dollars (1985 dollars). The fund distribution under this scheme could be:

* CHER Studies on Baseline Costs of Commercially Available Energy Alternatives. The cost quoted needs revision for cooling water system acceptable alternatives.

In terms of 1985 dollars, the contribution to OTEC from the Puerto Rico Government should be mainly for R&D, substructure facilities, laboratories, and operational R&D. This should be the maximum fixed by contract. This cost is equal to the energy production for the 450 MW coal plant discussed.

Approximate Cash Flow of Funds for Demo Project:

- PRIRA $26.2 million (plant investment)
- P.R. Gov. $26.2 million (R&D)
- Fed. Gov. $247.6 million (plant investment plus R&D)

Total: $300 million operational

The funds assigned by the Puerto Rico Government should be primarily for R&D, substructure facilities, laboratories, and operational R&D. This should be the maximum fixed by contract. This cost is equivalent to the energy production for the 450 MW coal plant discussed.

Government should be: Year 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | Day 3 | 3.01 | 3.97 | 3.93 | 4.09 | 5.26 | 5.86 D. Extrapolation to Larger OTEC Plant (Objective #2) If the results of the Demo Project are satisfactory, an extrapolation to build a 250 MW plant can be made with a high degree of accuracy. PRMRA can share a higher risk and the government also. It is expected that such a plant would cost $1500/kw in terms of 1978 dollars.

The cost of such a plant would be: Investment charges: 2500 million dollars (1985 dollars) and in terms of 1985 dollars = 30.2 million = 20.1 mills. O&M costs will be assumed to be twice the staff cost (1978 dollars.) (9,506,000) x 2 = 10.2 million dollars. The levelized 1985 dollars will be: (20.2)(2.5)(2.75) = 26.7 mills. The total cost is 56.9 mills/kwhr. This is much lower than a fossil plant. PRMRA can finance it completely.

Risk Analysis Considerations (Demonstration Plant of Objective No. 1) Since PRMRA is a public corporation, it has to operate under sound economic policies in order to market its investment bonds in the open bond market. It cannot invest in any venture without taking a calculated risk. The percentage of investment funds assigned to PRMRA in the preliminary economic analysis presented here is 8.733% of the total funds.

Feasibility Design Studies - Deep Oil Technology Inc., Subsidiary of Fluor Corp. Unpublished. February 1979.

If we correlate as a zero order approximation the risks of project success to the investment by the private sector on a one-to-one correlation between risk and investment, then we can assume that if the chances of success of OTEC are better than 8.733/100, the PRMRA is taking an acceptable calculated risk. We feel the risks of OTEC success can be conservatively figured on a 50/50 basis. The balance is to be provided by the government. We also feel that the Puerto Rico government, in undertaking the same risk as PRMRA, is taking an acceptable risk. It is promoting a needed energy alternative which will be multiplied by...

Various orders result in additional revenues. Studies by CEER that are currently under consideration will quantify this benefit for Puerto Rico's Treasury and the general welfare. Puerto Rico will be taking a combined risk of 17.46/100 and the Federal Government will take the balance. We believe that a more refined calculation in risk analysis and project covering should be worked out as more time and funds become available to CEER.

After the first OTEC plants become operational, RED funds need to be secured for the improvement of the existing embryonic technology and to address technical problems that might arise. The foam GTEC concept, currently under investigation by CHER, should receive more detailed consideration then. A yearly assignment is necessary.

Moving on to OTH Environmental Research Scenario, the primary environmental issues associated

with OTEC appear to be related to the following:
1. Heat exchanger design
2. Intake design
3. Discharge design
4. Working fluid design
5. General unit configuration

All the above factors impact the process of site selection. A schematic of the interrelation between the technology development, the development of needed environmental information and economic/aesthetic considerations is presented as Figure 1. It is assumed that the funds for environmental research are included within the allocations already mentioned.

Moving on to Figure 1, it shows the OTEC environmental project, highlighting the environmental, economic/aesthetic technology information needed:

1. Heat Exchanger Design: Biofouling potential influences the efficiency, control, cost, and methods of different configurations, materials, and modes of operation.
2. Intake Design: Empingement potential obstruction reduces efficiency and entrainment potential can lead to a reduction of biotic stocks.
3. Discharge Design: Field effects of different plankton redistributions.

Reorientation Configurations and Alteration of Fish Operations
The alteration of primary influences on productivity in the food chain, and alterations in currents, can lead to significant changes in fisheries. This can also affect environmental distribution and temperature. One significant concern is the bioaccumulation of heavy metals in food chains, which can ultimately lead to human exposure.

Working Fluid
There are several potential field effects of design leaks, such as direct human injury, direct kill of organisms, and chronic toxic or stimulatory effects. These could lead to shifts in communities, losses of economically important species, and losses of aesthetically important forms, impacting tourism.

II. Photovoltaics
A. Program Objectives
1. Small-scale demonstration (162W) project to be located at CHER. This small project will provide know-how to deal with this new technology and will develop much-needed human resources to tackle larger projects. The project is expected to be operational by mid-1980, with data gathering thereafter.
2. Electric Power Installation in the higher insolation areas of Southwestern Puerto Rico aims to provide 250W photovoltaic installation by the year 1993, and an addition of 250W photovoltaic plant capacity by the same year.
3. A cogeneration project to develop power and steam in an industrial park with the photovoltaic plants.

B. Photovoltaic Economics in P.R. Scenario
1. Storage Criteria for P.R. It is assumed that 1/3 of the energy output of the photovoltaics during

daylight time (8 hrs) will be delivered directly to the load, and 2/3 of the energy generated during the same daylight time period will be stored.

Note: The KW power values indicated are on a 24 HR continuous rating (storage included). Assuming an average of 8 hours insolation in the 24 hr daily cycle, the solar plants will have a peak capacity of three times the average 24 HR rating.

For delivery during night hours (16 hrs), this requires a 1 KW plant peak capacity for 8 hours to deliver a 1/3 KW average capacity for 24 hrs. The charging rate capacity of the storage system will be, on an average basis, twice its delivery rate.

Provides an emergency "spinning" reserve of three times the continuous rate capacity of the photovoltaic installation for the electric utility. The storage system can be discharged at the same rate as its charging rate. Credit for the extra "spinning" reserve capacity can be given at the rate of the capital cost of a conventional gas turbine. To account for the absence of solar radiation during rainy days, overcast skies, and storage system maintenance problems, an additional 25% energy storage will be provided. At an efficiency of collection and production of 4.5% and average insolation power of 7 KW-hr. per square meter per day, the required area for producing 1 KW of continuous power is: 3x ___ 8 meter = 76.2 square meter.

The average insolation power per square meter is 1/24 or .292 KW per square meter per 24 hour day.

2. Investment costs

The cost of a photovoltaic installation can be approximated by the following relationship: Plant cost $= Insolation Power + Power Conditioning Cost ($) + Storage Cost ($). The following values are assumed from the present-day technology and extrapolation of the same. 1977 dollars:

(1) Total array efficiency = 4.5%
(2) Array cost Solarcell cost: 1.0 mill/square meter or $10.00/square meter
Wiring, structure, installation cost/square meter: $10.00
Total array cost: $20.00/square meter
(3) Storage cost per kWh: $25
(4) Power conditioning cost per kW: $50

Plant Costs = 0.250256 + 50 (0.45) (0.292) = 1522 + 500 + 50 = $2072/kW

A $200/kW could be credited due to twice available reserve capacity, but will be neglected.

(1) Costs of gas predicted by Unesco for 1993.
(2) Same as cost predicted by Unesco.
(3) Costs of $20.00 per kWh predicted by Unesco.

Solar electricity and economic approach to solar energy- Wolfgang Palz energy development program, Commission of European Communities Brussels. UNESCO 1978

3. Land and land rights charges:

The area required for the plant (at a rate of 76.2 per KW) is 4760 acres of land. An area of 5000 acres will be assumed at $2000 per acre.

The land cost is $10,000,000. The total plant cost is $518 x 108 for a 250,000 kW plant from 2072. The land is 5,000 acres at $2,000 per acre. The investment charges in mills/kWh are 108.

The scheduled and forced outage rate for photovoltaics must be lower than for an OTEC plant, for which an 85% capacity factor has been assumed. We believe that three weeks of outage per year for photovoltaics is more than adequate for forced and scheduled maintenance. This results in a 94% capacity factor.

The investment charges at a 10% cost of money and 94% capacity factor will be, in terms of 1977 dollars, investment charges in mills/kWh = 28 x 108 = $.026 (8760) (250,000) (.94), which equals 26 mills per kWh.

Operation and maintenance costs will be calculated based on an assumed 33-34 plant staff. The area per kW of plant power is 76.2 acres, therefore, for a 250,000 kW module, an area of 4,760 acres is required.

The following staff is assumed: 1 Superintendent, 2 Assistant Superintendents, 2 Secretaries, 5 Shift Supervisors, 10 Shift Operators, 2 Electrical Engineers, 4 Electricians, 2 Electronics Engineers, 4 Electronic Technicians, 1 Instrument Engineer, 4 Instrument Technicians, 1 Mechanical Engineer, 3 Mechanics, 2 Clerks, 2 Sanitors, 5 Landscapers, 20 Security Guards (4 guards per shift), 5 Shift Chauffeurs, 1 Regular Chauffeur, 3 Utility Men, 2 Chemical Engineers (for storage system), 8 Assistant Chemists (for storage system), 1 Warehouse Supervisor (for spare parts), 2 Warehouse Clerks, 1 Accountant, 1 Purchaser/Estimator, 1 Clerk.

The total staff is 93 people with an average salary of $24,000 per person, resulting in total salaries of $2,232,000.

Assuming a factor of 1.0 for material replacement, etc., (which we believe to be a very conservative assumption since photovoltaics is a static system), the total operation and maintenance costs will be $4,464,000.

Therefore, the operation and maintenance costs in mills/kWh will be 2.1 (4,464,000 / (250,000 x 8760 x .94)). The total cost, including investment and operation and maintenance, will be 27.1 mills/kWh in 1978 dollars.

As for the 1985 dollars cost, the same factors for OTEC are applied.

Concept: Total Escalation for Investment (1979-1985) = 1.5. The Total Escalation Factor for Salaries (1979-1985) is also 1.5. The levelizing factor for Plant Life for Escalation of 0 M=175. The investment is calculated as follows: (26) (1.5) equals 39.0 for Operation (2.1) (1.5) (1.75).

The cost of an equivalent coal plant is 92.5 mille/ih (450 Mt coal plant). The photovoltaic concept cost of energy is 48% of the cost of a 450 Mw coal plant. The project should be suitable for commercial financing. The cost of the plant itself, estimated at $2072/iw, can be twice or higher in cost and still the plant will be competitive with coal.

A Cogeneration Photovoltaic Project is another consideration. The economics of photovoltaics look very promising in the P.R. Scenario. Since a photovoltaic installation takes a very large area, a power plant site needs special consideration. An industrial park can be developed adjacent to the photovoltaic plant where process steam is produced during the daylight hours from the waste heat of solar collectors and backed up with oil-fired boilers or biomass-fired boilers during the night hours. Such a system will offer great economic incentives to industry. The magnitude of this project will require detailed research which is being performed at CEER on photovoltaics and waste heat collection.

2. Photovoltaic Cogeneration project cost estimate:
a. 250 MW Power Plant Cost: $467 million
b. Cogeneration Cost Estimate (for evaluating the level of R&D funds requirement only): About 4 KW thermal power is produced for every 1.00 KWE produced in the CHER 150 KS cogeneration project under consideration. A steam flow of 2,122 lbs/hr at 220°F with an enthalpy of 765 BTU/f is predicted alongside a fan output of 151 kve. There is no condensate return in the CEER project. For a large co-generation project, condensate will have to be returned. Assuming 10°F condensate (obtainable with seawater once thru condenser), the amount of heat that can be extracted is approximately 900 Btu/Ib of steam. This is equivalent to 12,600 Btu/hr. of thermal heat.

Delivered per kW-hr of electrical power generation, the total amount of heat that can be delivered in a large co-generation project of 250,000 KW will be 3.15×10^9 Btu/yr. Note that the 250,000 KW is the average 26 hr. daily generation. The plant's peak power capacity is three times higher, and it stores all the 24 hr. energy in the assumed 8 hrs. of daylight. With an 80% capacity factor of the steam portion, yearly generation in thermal heat is 2.2×10^{19} Btu/year. Figuring conservatively, a $2.00 per MMBtu steam cost for a competitive project, total gross yearly revenues are $44 million. The cogeneration project level of investment will therefore be in the order of $800-900 million. For any such project, the R&D funds are figured at 6%. A level of $50 million will be required for the R&D of such a project.

Since the project is predicated under an economical basis, with electricity being nearly half the cost of a coal plant, and steam cost much lower than from an oil fired plant, the project can be funded by financial enterprises on a commercial venture with PREPA, Fomento, and the Puerto Rico Government. The project could be in operation by 1991-1992. It is assumed that the Puerto Rico Government can contribute 50% of R&D Funds and the Federal Government with the remaining 50%. Puerto Rico Government's assignment to this project is at a level of $25 million (1979 basis).

The funding distribution is estimated as follows:

Research Funds for Photovoltaic Cogeneration

Year	Puerto Rico Funds	Escalation	Actual
1979	$10 million	-	-

1980	$50 million	1.08	$38 million
1981	$70 million	-	-
1982	$1 million	1.26	$1.26 million
1983	$2 million	1.36	$2 million
1984	$4 million	1.59	$5.88 million
1985	$5 million	-	$7.95 million
1986	$5 million	1.85	$7.4 million
1987	$4 million	2.00	$4 million
1988	$2 million	2.16	$1.62 million
1989	$2.33 million	2.5	$40.73 million

Advanced Photovoltaics Concepts R&D funds for advanced concepts and material research as well as improvement of existing operations facilities should be allocated at least at the level of $1 million yearly (1979 basis) beginning in 1987. When escalation is figured at 8% per year.

Year from the base year 1979,

The following is the net result:

ADVANCED PHOTOVOLTAICS CONCEPT FUNDING ($)

Year	1988	1989	1990
Funding	1.85	2.0	2.5

Environmental Research Scenarios for Solar Photovoltaics: The primary environmental questions arising from this technology have to do with:

1. Site selection, given areas of land involved and
2. The actual construction effects on the sites.

The first question requires research by resource economists and ecologists on the alternate uses of the land including evaluation of the possible destruction of rare and endangered life forms. The second research effort is primarily of the nature of an Environmental Impact Statement and might properly be subcontracted to a qualified industrial/environmental engineering firm. It is difficult to estimate the costs of environmental research efforts required, but it will be assumed that such costs are included within the allocations indicated.

Title: Bona A, Program Objectives (In addition to actual program of species identification and production optimization):

1. Design, construction, and operation of a pilot boiler plant with a capacity of 1000 tons of biomass fuel per day achievable by modification of an existing sugar mill. Project can be operational within 12 months after initial authorization, including the collaboration of the PR Department of Agriculture and the Sugar Corporation. Boiler size is comparable with a 62,500 kW electrical power plant boiler and is considered large enough for a sevenfold extrapolation to an acceptable 450 MW boiler plant.

2. PRWRA shall be ready to request bids for 500 MW steam boilers suitable for burning any of three fuels (coal, oil, or biomass) by 1981 or 1982, and have an operational plant ready for 1987 or 1988. An additional unit could be operating in 1989. A 500 MW plant operating at a 75% load factor will supply 10.7% of the energy needs by 1990.

3. Routine considerations to be given by PRWRA, under available technological know-how and market conditions.

For the evaluation of biomass on a competitive basis with other available alternatives for future electric system additions beyond the year 1990, we have created two scenarios.

1. Pilot Boiler Plant: It is estimated that a two-year project demonstrating a 1000 tons per day pilot boiler plant, operational on a 12-month basis, will cost approximately $2.5 million in sugar-mill modification and logistics considerations, plus $400,000 for one-year operation and data gathering. About one-third of the investment will be in the biomass production phase, with special reference to off-season biomass production during a nine-month interval when bagasse will not be available.

To produce this fuel, the project will require land rentals in the order of 4,000 acres from the Department of Agriculture ($160,000/year for two years), irrigation water charges ($96,000/year for two years), purchase of four, 15-tower center pivot irrigation systems with pump and diesel engine installations ($380,000), and purchase of biomass harvesting equipment ($250,000).

The Department of Agriculture budget is estimated at $512,000, and total production costs at $1,142,000. With the addition of unforeseen cost items, the total value of the two-year project is estimated to be $3.9 million. Continued production and operational charges for years 3, 4, and 5 are expected to total $2.05 million.

This project will provide industrial-scale data related to a. Biomass production b. Logistics of biomass harvesting, drying, storage, transportation, and incineration c. Logistics and costs of biomass-delivery technology d. Furnace performance and design.

Since the pilot project cannot be evaluated under a competitive economical basis, its costs will be added to those of a commercial project identified under program objective 2.

2. Large Scale Plant Project: Calculations for a 450 MW plant will be made in terms of 1985 dollars in order to compare with a similar coal-fired unit. The cost of the power plant to burn coal and biomass will be dependent on investment charges.

Coal Plant: $683/kw (1978 dollars)
Biomass plant: A credit of $28/net kw can be given to the biomass plant for the unneeded equipment to burn no-sulfur fuel, but at the same time, additional requirements will be necessary to burn both coal and biomass in the same boiler. It is assumed these two costs cancel out. The cost of the biomass-burning plant is tuned to be the same as the coal plant.

Biomass power plant: $683/kw (1978 dollars)
Investment charges: Same as for the coal plant
1985 dollars: 23.2 mills per kwh (CEER energy studies).

Fuel Cost: The fuel costs for biomass have been figured at $25 (1) per ton delivered with a heat content of 15,000,000 BTU per ton. This yields $1.66 per million BTU delivered fuel cost (Alex Alexander information). This cost is taken as 1979 fuel cost. Assuming the same carrying charges for a biomass stock storage of 3 months as was assumed for coal, the carrying charges in biomass is 1/6 (1.66) (.1) or 4 cents per million BTU. The fuel costs at 1979 dollars level is therefore $1.70 per BTU including 3 months stock storage charges.

This includes $1900 per ton production cost and $6/ton transportation. Drying of biomass will be on the field, cut and scattered. Bales or bundles are truck transported from the field to the electric power plant storage pile.

Levelized fuel cost 1985 dollar, 7 1/4 % escalation.
1985 Fuel Cost = (1.70) (1.0725)^6 MMBTU
Levelized (35 years) cost = 1.75 (2.59)=$4.52/MMBTU.
With a plant heat rate of 10,000 Btu/kwhr (at 75% capacity factor).
Levelized fuel cost is 45.2 mills/kwh.

Operation and Maintenance of the biomass operation will be taken equal to 2 coal plants less the operation maintenance of an FD System. This estimated cost for the Desulfurization System for a coal plant is = STR (401 + 10Pqq) (LP) (1 +)", where S = sulfur content of coal 2/100, Py = price of Limestone $/ton, TR = coal firing rate tons/hr, Pqq = price of sludge disposal $/ton, LF = plant coal factor = escalation, Y = years between time of estimate and.

Beginning of Operation. Refer to the CHER energy study for levelization theory. This theory takes into account the rising costs during the plant's life. 1 ton of sulfur requires 4 tons of limestone to produce 5 tons of dry sludge. This dry sludge is combined with 5 tons of water to produce 10 tons of wet sludge, which requires disposal.

Using the same figures for the coal CEER plant study: PL = Pyd = $5.50/ton; B = .03; Te = 200 tons/hr.; LF = 75%; Y= 7 years; e = 0.8.

Substituting the above figures into the formula gives the desulfurization plant's OM cost as $5.2 x 10^6/year. The equivalent OM cost in mills/kWh for the FOD system is (5.2 x 10^8) / (414,000 x 75 x 8760) = 1.91 mills/kWh.

The levelized 35 years OM for FOD System levelizes the OM cost: FoD = (1.91)(1.75)= 3.35 mills.

The total O&M levelized cost for a coal plant has been determined at 3.3 mills.

The O&M cost for a biomass plant is 12.0 mills/kW.

The coal plant's gross capacity is 450,000 kW, and the net capacity will be 414,000 kW.

The factor of levelization of 1.75 is derived in other CHER studies. It levelizes the effect of increasing escalation of operation and maintenance during the plant's life.

The total cost for the biomass plant's 35-year levelized cost (in 1985 dollars) is:

Investment (same as coal plant) = 23.2 mills
Fuel = 45.2 mills
O&M = 12.0 mills
Total (Biomass fired plant cost) = 80.4 mills/kWh

The comparable cost for a coal plant is 92.5 mills/kWh.

If the 80.4 mills/kWh is corrected for the investment of 6.00 million (escalated) research funds invested in objective number one, the correction is rather small—equivalent to .000357 mills/hr. The R&D funds will be more than recoverable in the program. Plus, the multiplying factor in the Puerto Rico economy of a billion dollars reinvested in local fuel of biomass versus coal or oil more than pays for the project. The second and third objectives of the program can stand on their own economical basis.

Energy Research Funds Requirements for Biomass (in millions) from 1979 to 1985 are as follows:

1979 Base = 2.0
1980 = 1.0
1981 = 1.08
1982 = 1.71
1983 = 2.62
1984 = 1.47
1985 = 1.59

The actual figures are 2.16, 0.59, 500.54, 59.64. Recent revisions by Dr. A. G. Alexander indicate small additional total funding requirements in the order of $930,000.

Advanced Biomass Programs

For the development of advanced programs such as fluidized bed systems, pelletizing, cycle improvements, and technical difficulties of developed methods that need improvements, a yearly assignment of 3/4 million in 1986 and $1 million thereafter is allocated (1979 basis). When escalated at 8% per year, the result is: ADVANCED BIOMASS PROGRAM DEVELOPMENT (in millions $).

1986: 1.85
1987: 2.00
1988: 2.16
1989: 2.33

Environmental Research Scenario for Biomass

The primary environmental issues associated with biomass fuel include:
1. Atmospheric emissions quality and quantity, and potential toxicity to humans and other biota.

2. Residue disposal including possible beneficial uses of the ash as soil amendments.

Secondary environmental research that ought to be pursued is the possible coupling of sewage and other waste disposal to the rearing of biomass to alleviate the fossil fuel subsidy required for high biomass yields. Biomass production requires land and site selection.

Consideration needs to be given to the possible alternative uses of the land, as in the case of photovoltaic generation. It is difficult to estimate the cost of the research program for a biomass program. However, it is assumed that such costs are factored within the allocations indicated.

IV. Ethanol (Motor Fuels)

A. Potential and Economic Implications

Gasoline consumption in Puerto Rico during the last fiscal year (1977-78) was 678 million gallons. Gasoline consumption has been increasing and is presently increasing at the rate of 6.62% annually during the last twelve (12) years (1966-1978).

Ethanol could be produced from sugar cane as a motor fuel substitute at prices which will be competitive with gasoline by the time that a project to produce and market ethanol can become a reality. Predicted costs of ethanol are in the ranges of $1.00 to $1.25 per gallon.

The equipment and facilities required are existent in Puerto Rico and they will require relatively nominal investments for conversion. Cane juice is extracted by conventional sugar cane milling tandem. Juice is clarified in existing sugar mills. The process involves the usage of clarifiers and rotary vacuum cleaners and is concentrated to about 20% total sugar content. From this step on, a modification is required to the sugar mill. This modification involves yeast fermentation of the concentrated juices (fermentation can last 12-18 hours) and distillation of the same. The cost of additions is in the order of 10-15% of the investment cost of a sugar mill. In the sugar industry, bad weather or rain is a detriment to the sugar sucrose yield which reduces the revenues of the farmers. This is not so for alcohol production, and on the contrary, it will be an asset.

The production of ethanol from sugar cane and of electricity from the sugar cane bagasse combined with the utilization of cane waste is a very attractive program. Ethanol yields today from sugar cane is 15.6 gallons per ton of green sugar cane. Today the average production of sugar cane in Puerto Rico is approximately 28 tons per acre. Alexander has estimated that with a program partially optimized for biomass, yields as high as 29 tons of dry biomass (116 green tons per acre) are obtainable today. The ethanol yield would be 1800 gallons per acre. Historically, experience has shown that yields under actual field conditions are much lower than under controlled conditions.

The potential of sugar cane as a renewable energy source for developing tropical nations is significant. However, it is logical to expect lower yield of ethanol per acre than the indicated figure. For the purpose of this calculation, we will assume 1000 gallons of ethanol production per acre with 65-75 green tons of sugarcane per acre and 18 tons of dry biomass. In order to produce the same, certain modifications and investment will be required.

To produce an equivalent amount of ethanol to the gallons of gasoline consumed last year in Puerto Rico, a total of 658,000 acres will be required. However, due to the lower heat content of ethanol, this will be equivalent to only 60% of gasoline requirements. Additionally, this plantation could generate the total energy required by the ethanol plant and produce 50% of all the electricity requirements for the year 1982 through the burning of bagasse. The acreage indicated represents 50% of the total agricultural land in Puerto Rico. The implications for the sugar industry and the energy situation in Puerto Rico could be far-reaching with such a potential program. However, before any major scale operation is attempted, it is necessary to develop realistic information pertaining to all the technical data and the economic evaluation of a project to produce ethanol and biomass for electricity.

3. Program Objectives:

1. Selection of Saccharum hybrid candidates for evaluation in a combined production of ethanol and dry biomass. The agricultural part of this program is under the direction of Dr. A. G. Alexander and suitable candidates have already been identified.

2. Evaluation of the ethanol production at a pilot plant level. A proposal for a pilot plant capable of producing 600 gallons per day is under preparation and will be ready by May 30, 1979.

3. Conversion of a sugar mill to handle 4000 tons of sugar cane per day and produce 62,500 gallons of ethanol per day (approximately 2.0% of gasoline consumption during 1977-78) will require an investment of $1.75-2 million dollars in additional costs plus RED funds. This project is intended to function in parallel with the biomass boiler project, which requires 1000 tons of dry biomass (4000 green tons) per day. The project is expected to be operational by the year 1983.

4. Large Scale Operation - Goal for 1986: Ethanol production to equal 11% of 1990 gasoline requirements. The investment cost for a new project is assumed to grow at a reduced rate from the present 6.6% per year to 3.3% per year. The total 1990 gasoline consumption is predicted to be one.

Billion gallons. One gallon of gasoline is equivalent in heat content to 1.67 gallons of ethanol.

A facility optimized for ethanol production costs $225 million. However, the cost could be reduced to $60-105 million if existing sugar mills are repurposed. Economic studies of both alternatives are required. In addition, optimization studies of ethanol for electric energy and electric cars scenarios need to be considered versus ethanol for cars. Electrical generation with bagasse could meet 50% of the fuel requirements of a 500 MW electrical machine at a 75% capacity factor (equivalent to 10.7% of the electrical energy needs in the year 1990 as stated under objective number 2 of the biomass program). The investment cost is equivalent to a coal-fueled electric plant, of $325 million. It was shown that the alternative of direct firing of biomass for electricity generation alone was competitive with coal. The combination should yield additional economic advantages. The agricultural land requirement for both alternatives combined will be twice the value estimated for biomass alone, due to the lower yields used.

R&D Fund Requirements:

The estimated R&D costs of this project, based on using existing sugar mill facilities and a total project cost of $150 million, at 6-72% of cost, is as follows:

ETHANOL R&D PROGRAM FUNDS REQUIREMENTS (in millions)

Year	Factor	Actual	Escalation
1980	50	1.08	54
1981	1	1.00	1.7
1982	1	1.26	1.26
1983	1.50	1.36	2.04
1984	1.50	1.47	2.2
1985	2.00	1.59	3.18
1986	0.75	1.1	0.83
1987	0.50	1.85	0.93
1988	0.25	2.00	0.5
1989	0.25	2.16	0.54
1990	2.33	2.58	6.01
Total			12.64

Advanced Concepts for Ethanol Research:

Research for the production of ethanol at lower costs include increasing yield production, new methods of fermentation and distillation, and new cycle optimization methods. Improvement of technical difficulties of the first ethanol-funded plants will also require research. For these purposes, $0.25 million is assigned for 1985, $0.8 million for 1986, $1 million for 1987, and $1.5 million for 1988.

For the years 1989 and 1990 (in 1979 dollars), after escalating the indicated allocations, the following results were obtained:

ADVANCED CONCEPT ETHANOL FUND REQUIREMENTS (ESCALATED) $ MILLIONS

1985	986	1987	1988	1989	1990
4	0.8	1.85	20	3.26	3.5

These figures represent an Environmental Research Scenario for Ethanol. The principal environmental impact of ethanol production is anticipated to be related to the disposal of the rum stillage for "mostos", which are known to be toxic to marine life at concentrations currently released. Research is needed to determine ways in which the useful components in the mostos may be recovered for their energy and/or nutrient (fertilizer) value. This would enable the former waste to become a by-product.

Solar Sites A, Potential and Economic Implications:

Steam can be produced by direct solar concentration. In the production of ethanol as a motor fuel substitute for gasoline, there is a requirement to the order of 15-24 lbs. of steam per gallon of ethanol. Steam can contribute to as high as 10% of the cost of ethanol with today's fuel prices. Reduction costs could be achievable in the range of 5-7% if solar energy is used. This percentage fractional cost will increase with the increase in fuel oil costs. Other industries using steam could probably achieve cost reductions of a larger magnitude.

GEER has developed a solar collector that is a linearly segmented compound parabolic concentrator (CPC) with a cylindrical evacuated tube as a receiver. The collector has a concentration ratio of 5.25. The efficiency of collection of solar energy is estimated at 55% at 350°F steam. It makes use of direct as well as diffuse radiation of sunlight. It doesn't require daily tracking of the sun's position and as such is a very low-cost, efficient collector that can be used to produce solar steam at a very low installed cost.

Currently, there is a project to produce steam for the Bacardi Rum Distillery in Toa Baja (Palo Seco), co-sponsored by Bacardi. The results of this project can be extrapolated.

Large industrial type of installation. 'The proposed large-scale ethanol facility in Section IV will require approximately 100 million pounds of steam per day. Assuming all steam requirements are produced by solar radiation, about 1000 acres of surface will be required to produce all the steam. Assuming a utilization of 67% of land, a total of 1500 acres will be required. It is not logical to assume full production of steam by solar radiation, because the ethanol facility will have to operate on a 24-hour basis. One third of the steam requirement could be assigned to solar energy. This will require 500 acres. About 17-20% more electricity could be produced by the electrical plant since now 33% more fuel in bagasse will be available for the electrical production. Very rough calculations indicate that this project will cost $200-250 million dollars, could produce 10-15% profit on investment and sell the steam for half the cost of an equivalent oil-fueled plant ($2 vs $4 per 1000 pounds of steam).

Program Objectives:

1. Economical feasibility and optimization studies and design to provide steam in the order of 33 million pounds per day to an ethanol plant (producing 11% of the gasoline requirements by the year 1986).

2. Develop the R&D Program to make a reality of such a project operational by the year 1986.

3. Extend the technology for general industrial uses by the year 1988 to the level of 5 percent of industry oil requirement for the year 1988 and 10% by 1990-1995 requirements.

R&D Funds Requirements:

The R&D requirements are figured as follows:

1980 - 2
1981 - 2

1982 - 3
1983 - 38
1984 - 1
1985 - 20
1986 - 38
1987 - 5
1988 - 8.35
1989 - 2
1990 - 3.70
1991 - 3
1992 - 4
1993 - 1
1994 - 14.60

Advanced Concepts for Solar Steam:

R&D funds will be required for materials improvement programs which will result from the operation of the first installations, efficiency improvement for greater yield per solar collection area, etc. The escalated allocation for this.

Program I: Advanced Concept for Solar Steam Funding (Escalated) ($ Millions)

1985: $8 million
1987: $185 million
1988: $20 million
1989: $2.16 million
1990: $2.33 million

Environmental Research Scenarios for Solar Steam

The same environmental considerations given to the photovoltaics and cogeneration concepts apply to the solar steam concept.

Summary Table of Total CEER Funding Requirements for Example Scenarios

Total CEER Fund Requirements for Table 6 (Cols. 1-12)

Photovoltaics, Biomass, Ethanol, and Solar Steam R&D Programs

Million Dollars:

1980: $5.8 million
1981: $2.16 million
1982: $6.45 million
1983: $3.97 million
1984: $2.39 million
1985: $6.77 million

1986: $3.03 million
1987: $1.26 million
1988: $2.5 million
1989: $2.16 million
1990: $2.33 million

Total 1980-1990: $26.2 million, $10.02 million, $40.79 million, $8.24 million, $6.02 million

Summary Tables

Table 2: Estimates of Puerto Rico's Energy Requirements for the Year 2000 under Present Socio-Economic Structures and Absence of Strong R&D Program on Alternate Energy Sources

Year: Estimated Consumption of Diesel, Electricity, and Total Cost

1976: Diesel - 21.7, Electricity - 128, Total Cost - 26.3
1977: Diesel - 33.0, Electricity - 18.2, Total Cost - N/A
1979: Diesel - 23.5, Electricity - 137.9, Total Cost - 26.0
1980: Diesel - 25.1, Electricity - 17.9, Total Cost - 36.3
1981: Diesel - 16.78, Electricity - 120.3, Total Cost - 29.0

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10.6 ‘0.02 (2) Estimated to take per ton of (S18 moisture) bagasse. Page Break. ‘TABLE 4 POTENTIAL "ENERGY AND COST REDUCTIONS" FOR EXAMPLE SCENARIOS. 2 are why 5 (6) So ENTILTON FRACTION TO MILLION BARRELS OF - Page Break - 10° OIL DOLLARS (OF SCENARIOS) year [no ‘WHERE EXAMPLE - SAVINGS SAVINGS SAVINGS OF scenarios | scenarios | with scenarios| with scenarios | TOTAL-NON SCENARIOS| 1905 | 09.9 99.37 0.53 17.33 oss. 1986 [93.4 87.76. 3.68 7487 a a7 -96:9, 35.96 Wo:54 rn ae 985 [703.6, 35:53 18.07 oo ae 585 | Y08-8, 3540 23.40 Tr160 aie 1990] 103.9 3013 S377 11857 308 390 96.13 33:7 T1364 28 992 tas 33.77 zn 2 993 20:50. 24 2 983 ae 31138 ae 3995, S284 aoan, Sr 7996, 60.08 668. ay 3997, 66.38. 5,709, ae 1998) 73:35 6,886. ae 3999) 30.02 7732 are 2000 30.02 B20 a6 1435.62 657.18 1,909.0, 26 2 108 _.145,966. 6 - Page Break - TABLE 5 POSSIBLE OTHER REVENUES FROM FUELS TAX REDUCTION LAW. YEAR[CONSUMPTION . with sve] oy s108] 8 5108 | SCENARIOS 1900 | 71.70 6.45 10.53 1961 75.2 6:77 |0-47 1982 77-80 33a O35 7363] 82.20 4:86|0-48 1964 —| 96:10 =r 3985] 09-37 Has. 3986] 27.76. =a 7967] 85.96. a7 1988 95.53, 33s 1969 85.40 330 1990_—[80.13 227 1991 [65.13 236. 1992 | 91-43 22a 3933 | 90:30, 2 7398 az 985. 20, 1996. ae 7957 a7 990] e895, He: 3999 | 68-58. aie. 2000 [95.58 a5 66 - Page Break - Page Break - ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO APPENDIX E ‘LONG RANGE FORECAST OF ENERGY NEEDS IN PUERTO RICO CENTER FOR ENERGY AND ENVIRONMENT RESEARCH UNIVERSITY OF PUERTO RICO 8 April 1979 - Page Break - APPENDIX LONG RANGE FORECAST OF PUERTO RICO'S ENERGY NEEDS ELECTRICAL

ENERGY FORECAST AL General ‘The problem of forecasting long range estimates of energy use is a rather difficult task because of all the uncertainties involved in the development of new technologies and changing habits which will affect considerably the estimate. An attempt has been made to forecast for a length of period in which present embryonic technologies could be

The text is extrapolated in a qualitative sense. A 40-year period, up to the year 2000, is believed to be long enough to provide for such an extrapolation and at the same time provide energy planners with an overview of the next four decades for adequately focusing on energy alternatives. CEER's interest is mainly in the energy or fuel alternatives scenarios, which are required to power Puerto Rico's socio-economic development; therefore, the forecasting has been restricted to the total electrical energy generation, which is responsible for the fuel consumed in the electrical plants. Classical statistical regression analysis was used. The approach adapted was as simple as possible so as not to complicate the prediction with complex relations and hypotheses such as postulating saturation functions, etc.

The prediction of energy generation requirements is recognized to be based on two main factors: Population and economic welfare or income per capita of the population. These factors were analyzed statistically in making the prediction. After the mathematical relationships were established, judgment from past experience and insight of new technologies and changing habits were considered to select the most appropriate relationship. The energy prediction was based simply on a correlation between total GNP at constant prices and electrical energy. The GNP was predicted from the product of population predictions, times the GNP/per capita prediction at constant prices. Populations have already been predicted by the Planning Board up to the year 2000, GNP up to the year 1983. Our predictions will be, therefore, somewhat uncertain for the period 2000-2020. Population is a very sensitive variable in the prediction of energy needs. Different government programs, economic welfare, social, and religious groups' attitudes may influence, to a certain degree, the population growth. Meléndez.

This text indicates that the growth rate of a nation's economy responds better to a moderate increase in the population, rather than a rapid growth rate as is the current case concerning Puerto Rico, where the population has doubled in less than 35 years. This information is according to "Economía y Población," a conference series by Dr. James A. Santiago Meléndez from the Department of Economics at the University of Puerto Rico, Río Piedras, Puerto Rico.

Alternatively, a slow population growth rate, such as doubling of population every 200 years, can also pose issues. Doubling times of approximately 50 years in the population is considered moderate and adequate to support economic growth. A rapid population growth rate can heavily impact a nation's infrastructure, resource balance, and require higher investments from outside sources. On the other hand, a slow population growth rate can create problems as the population ages, leaving not enough youth to replace those exiting the labor force. This issue has been experienced in certain areas of Japan.

The concept of optimal population growth is difficult to determine because of the many factors involved. The Planning Board has projected a population for Puerto Rico of 4,675,000 for the year 2000. Population predictions on a city by city basis up to the year 2020 have also been made.

In 1960, the population of Puerto Rico was approximately half of the projection for the year 2000, indicating a doubling of the population in this 40-year period. Using a linear regression analysis on historical population data dating back to 1962, and the Planning Board's projections up to the year 2000, the following equation is obtained:

$yp = 2166.9 + 65.05\, x$

In this equation, yp represents the population in thousands and x represents the year referred to the 1960 base year, (year less 1960). The coefficient of determination for this equation, $r2 = 0.98$, indicates a significant correlation.

AI Services: The total consumption of electrical energy by all sectors of the economy is very sensitive to this variable and can therefore be satisfactorily correlated. Statistical tests can determine how good the correlation is. The Planning Board has predicted total GNP values in current dollars up to the year 1983, indicated in Table IT below:

Planning Board Prediction (of GNP) Current Dollars ($ thousands)
1979: 9835.0
1980: 10750
1981: 11693
1982: 12710
1983: 13795

Constant $
1979: 4047.4
1980: 4298.8
1981: 4549.7
1982: 4814.0
1983: 5090.1

Constant dollars were estimated by assuming a 10 percentage point increase in inflation for the year 1979 and a 7 percentage point increase for the remaining years. The 1978 inflation factor relative to 1954 (the year that the Planning Board used to reflect constant prices) is calculated to be 2.33 from the Planning Board reports on current and constant dollars data. Using the predicted populations for the years 1979-83, the above GNP in constant dollars were converted to GNP per capita.

These data, together with historical data back to the year 1962, were then retrieved by statistical methods. Four types of regression analysis were tried, including linear, exponential, logarithmic, and power. The best fit correlated with a 97.5% correlation coefficient or a 95% coefficient of determination. This fit was: $y = 546.87\, x^{0.7}$, where y = GNP/capita in constant 1954 dollars, and x = year - 1960. Predicted values with the above equation indicate yearly improvements in GNP/capita at constant dollars of the order of 0.5 to 1.5 to 1.0%, which is considered adequate and on the low side. The predicted GNP per capita at constant dollars was multiplied by the predicted population to obtain the total predicted GNP at constant dollars.

Electrical Generation: The total electrical generation was correlated with the total. Results were as follows:

1) Coeff. of determination: 98%; doubling time: 20 years
2) Power Correlation: Coeff. of determination: 98.25%; doubling time: 1 year
3) Log Correlation: [To be continued...]

A statistical test indicated excellent correlations on all of the above. Of all of the above correlations, the log and exponential correlations are discarded because of poorer correlations relative to the Linear and power correlations and because of the very slow and very fast growth rates respectively. The Linear and power regression analysis represent reasonable selection projections.

Electric power generation has been doubling every 5 years during the 1960 decade. During the present decade, it has been doubling every eight years. A doubling time of 11 years for the 1980-90 decades is therefore, not unreasonable. Doubling times of the order of 20 years might be appropriate beyond the year 2000, at the same level of technology and habits are maintained.

It is felt however, that new technologies and new consumer goods will impact beyond present expectations on further needs of electric power. One example could be the development of urban electrical vehicles requiring nightly battery charging. This requirement might offset the leveling of power growth as predicted by a linear relationship.

Table III indicates the correlation data for population, GIP, and Electrical Energy. The figures given for electrical energy consumption are comparable to PRURA forecasts but they tend to be on the low side. Power Technology(3) prediction for the year 2000 is 38,261 x 10^6 KWHR generation which is comparable to our Prediction of 42,910 x 10^6 KWHR within a 5% difference. The

The prediction of electrical energy generation for the year 2020, as shown in Figure 1, using the above selected relationship, is 89,120 million Kw-hr. This is slightly over six times the current electrical energy generation. Energy planners and researchers must, therefore, think of energy alternatives for Puerto Rico on a scale as large as six times today's demand by the time when supposedly most energy alternatives being researched today could be economically competitive. Electrical energy is used round the clock; hence, large storage systems for direct solar-derived energy must be examined in perspective.

'Long Range Sales Forecasting Study for the Puerto Rico Water Resources Authority' by Kevin A. Clements and Robert de Mello, Power Technologies, Inc., Schenectady, N.Y., May 1976.

TABLE XT (GNP, POPULATION, AND ELECTRICAL PRODUCTION CORRELATION DATA CONSTANT PRICES (1954)

Fiscal Year | GNP/Capita | Population (Thousands) | GNP (Millions) | Electric Prod. (106 KW-hr)

(Note: The table data has been omitted for clarity.)

REFERENCES

'Statistical Methods for Decision Making', W. A. Chance, 1969. Irwin-Dorsey Ltd, Mokeleton, Ontario.

'Conferencia sobre Economía y Población', Dr. Jaime A. Santiago Meléndez, Serie de Conferencias y Foros: No. 4, Departamento de Economía, Universidad de Puerto Rico, Rio Piedras, Puerto Rico.

'Long Range Sales Forecasting Study for the Puerto Rico Water Resources Authority', Kevin A. Clements and Robert de Mello, Power Technologies, Inc., Schenectady, N.Y., May, 1976.

(Continued...)

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APPENDIX F 'PROPOSED PUERTO RICO RESEARCH INSTITUTE (CENTER FOR ENERGY AND ENVIRONMENT RESEARCH) - UNIVERSITY OF PUERTO RICO, April 1979

'PUERTO RICO RESEARCH INSTITUTE

The main purpose of the Institute is to serve the advancement of science and technology for the betterment of the Puerto Rican family and humanity as a whole. Among its main purposes will be the development of "know-how" principles and technology which will help local industry to develop and offer industrial products in the world market competitively and therefore advance economic welfare and standard of living. The Institute shall be a non-profit research organization. Energy research shall be one of its main areas of concern. It shall be incorporated under the laws of the Commonwealth of Puerto Rico.

The Institute will provide specialized research and advisory services, by contract, to solve specific problems for industry, government, foundations, and individuals. The Institute will undertake pure as well as applied research as indicated above. The Institute shall be formed by contributing members mainly private organizations, industry, professional organizations, etc., and the government. The greatest bulk of the research work is expected to come from Puerto Rican Government sponsored contracts on energy research field for which adequate cooperation needs to be obtained from the government by legislative action.

The Institute will be regulated by a set of By-Laws approved by its members. Approval and modifications of By-Laws will require endorsement by 2/3 of Institute members. The Institute will be governed by a five-member Governing Board elected freely by its members. Governing Board members shall be elected to serve for a period of five years in a staggering order. The Governing Board members will be constituted as follows: President, Vice-President, Secretary, Member and Member. The Governing Board will select its President, Vice-President, and Secretary.

Between themselves, the Governing Board shall meet at least once a month. The Governing Board will have no salary. A per diem will be assigned for every meeting of $35 per meeting, plus travel and other out-of-pocket expenses. Any person of recognized moral standing and any organization or corporation doing legitimate business can apply for membership. All Institute members will have a yearly due of $500. A down payment of 50 years' dues ($25,000) will make the member a Benefactor Life Member. A down payment of 30 years' dues ($15,000) will make the member a Life Member. Organizations or Corporations members will have only one representative with voice and vote. Each active member will have only one vote. Membership privileges include participation with voice and vote in all Institute members' meetings. They will receive copies of all unclassified Institute research project reports. Short general consultation and orientation from staff members is provided free of charge, and free use of the Institute Library will be provided.

The Institute will benefit from the membership of certain Government institutions. Adequate legislation should include incorporation of these institutions as Benefactor Life Members and authorization for payment of dues. Such Government Benefactor Life Members should include:

1. The President of the University of Puerto Rico
2. The Chancellor of the University of Puerto Rico-Rio Piedras
3. The Chancellor of the University of Puerto Rico-Mayaguez Campus
4. The Chancellor of the University of Puerto Rico-Cayey Campus
5. The Chancellor of the University of Puerto Rico-Medical Sciences
6. The Secretary of Agriculture
7. Manager of Puerto Rico Development Administration
8. Executive Director of PRIRA
9. Direct Representative of the Governor
10. Director of the Office of State Energy Affairs
11. Planning Board Chairman.

Each government member indicated above will have one vote at members meetings, making a total of __11__ voting members for the government by legislative action. Other government

Agencies or institutions could apply for membership on a voluntary basis.

Government contribution by State Legislative Assembly authorizations must be sought for permanent facilities and laboratory equipment. Some help on operating funds for initial operations may probably be required. All equipment and property bought with government funds will remain property of the government and will be identified properly, taken care of, and disposed of as regulated by the Office of the Controller. All direct work performed for the government will be by contract and such contract should reflect corresponding cost reduction for the use of government property. No official, member, or other party shall accrue financial benefit since this is a non-profit corporation. However, research projects shall be performed at cost plus some institute benefit to provide for self-expansion of permanent facilities, purchase of additional laboratory equipment, etc. It is expected that the majority of members will be from private institutions and local industry.

Members will have an annual business meeting in the month of November and will appoint the

Governing Board or fill whatever vacancy occurs in the Governing Board. No employee of the Institute who simultaneously holds membership in the Institute will be permitted to vote in the selection of the Governing Board Members. The Governing Board will preside at the member meetings and discuss the affairs of the Institute including financial, technical, research, etc.

At least two members meetings shall be held yearly. The Governing Board will appoint the Executive Officers. Executive Officers will be employees of the Institute. They include the President and the four Vice Presidents of the Institute as follows: 1) President 2) Executive Vice President-Contractual Relationships and Fund Raising 3) Vice President-Engineering and Research 4) Controller 5) Personnel Officer. There shall be as many divisions as found necessary.

Corrected Text:

All changes in organizational matters have to be approved by the Governing Board. The President will appoint the Division Heads in consultation with the Vice Presidents and with the endorsement of the Governing Board. All officers of the company shall be full-time employees, and they will have a salary as approved by the Governing Board. No officer can be removed from office unless proven guilty of misconduct, negligence, inadequate discharge of duties, incompetence, etc. All research projects sponsored by public funds shall be for the benefit of the government and the people of Puerto Rico. All research projects carried out with private funds shall be proprietary if so desired by the sponsoring organization.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX G: THE NEED TO EXPLORE ALTERNATIVE ENERGY SOURCES FOR PUERTO RICO

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INTRODUCTION

The quadrupling of oil prices by the Organization of Petroleum Exporting Countries (OPEC) at the end of 1973 has had a profound and permanent impact on the economies of almost all countries, including Puerto Rico. The initial impact was a sharp increase in the prices of almost all intermediate goods and services, and those that go to the final consumer. The increase in prices raised the production costs of almost all industrial sectors, thus reducing their productive capacity. The inflation that was followed by a severe recession increased the unemployment rate, reducing current production and increasing the "gap" between this situation and the potential output that would be obtained if the economy were using all its resources to its full capacity. It is estimated that the increase in the price of energy permanently reduced the economic capacity, or the potential production of the economy of the United States by about five percent.

Por ciento (1) reduciendo también en forma drástica la productividad del capital y la mano de obra. La producción de un sector industrial, o de la economía en su totalidad, dependerá del acervo (stock) de capital, de la mano de obra, otros recursos (como la energía) y de cómo se combinan estos. (Q) Robert H. Rasche y John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production and Prices", Federal Reserve Bank of St. Louis, Review (Mayo, 1977).

Recursos (la tecnología). Los precios que se pagan por estos recursos determinan los costos de producción. De tal forma que el aumento en el precio de energía afectó los costos de producción (dada la tecnología) lo cual tuvo un impacto adverso sobre la producción. En cuanto se afectaron los costos de producción va a estar determinado por la participación ("share") del recurso (el cual fue objeto del aumento en precio) en los costos totales. No existe la menor duda de que si no existe expectativa alguna de que hayan los precios del petróleo (y las empresas quieren minimizar sus costos) la alternativa será el cambio tecnológico y esto en términos del recurso de energía implica el buscar fuentes alternas de este recurso.

El Costo de Energía por Sector Industrial en Puerto Rico y Capacidad Productiva: Los sectores industriales de Puerto Rico necesitan del insumo de energía (combustible y electricidad) para llevar a cabo su producción. También el consumidor final demanda productos derivados del petróleo. En otras palabras, la industria de productos de petróleo vende su producto a otras industrias para ser usado como insumo intermedio, y a los consumidores finales. De igual forma lo hace el sector industrial productor de electricidad.

La Tabla 1 ilustra la demanda que hacen los diversos sectores industriales y el consumidor final de productos de petróleo en base al cuadro de relaciones.

Interindustriales de 1972 publicado por la Junta de Planificación. La Tabla 2 muestra el por ciento del total de costos que representa.

Gasté en productos (suministrado por la industria del petróleo) para los 25 sectores más intensivos en energía (en este caso, combustibles). Nótese que la propia industria de petróleo, la electricidad, minería, construcción y cemento son las industrias más intensivas en el uso del combustible, por lo tanto las más afectadas en caso de aumento en los precios del petróleo. El cuadro nos indica que los costos totales de producción (uso de insumos intermedios y el pago a los factores primarios de producción - capital, mano de obra, etc.) para la economía de Puerto Rico fueron de alrededor de $12,071.1 millones, de los cuales $491.9 millones fueron gastados por las industrias en consumo intermedio de productos de petróleo. El consumidor final gastó $70.8 millones en productos derivados del petróleo. La cantidad demandada por los sectores industriales constituyó el 4.1 por ciento de los costos totales (insumos intermedios más valor añadido) y el 8.8 por ciento del total de gastos en insumos intermedios. El porcentaje que constituye el gasto en insumos energéticos del total de gastos es una medida de cómo se afecta la capacidad productiva de la economía total, o de los sectores industriales, en respuesta a aumentos en los precios del petróleo. De acuerdo a un estudio reciente para la economía de los Estados Unidos y otras economías mundiales, "The percentage response of capacity output to one percent change in the price of energy is just equal to the share of energy costs in total factor costs" (2). Según los estudios citados la economía de los Estados Unidos perdió cerca de un 5% de su capacidad productiva debido a los aumentos en los precios del petróleo. Asumiendo que la producción total de Puerto Rico (igual al costo total) de 1972 se acercó al punto de máxima capacidad y asumiendo que el "share" de energía a costo total (combustible más electricidad - 4.1 por ciento combustible y 1.0 por ciento electricidad) es del 5 por ciento (según datos del cuadro de insumo-producto de 1972) podemos...

La capacidad productiva de la economía aumentará en cerca de un 5 por ciento de la reducción en precios. Si la reducción en costos implica una reducción en las importaciones de la misma magnitud, el producto bruto de la isla aumentaría ya que habría un incremento favorable en el saldo de nuestra economía con el exterior (aumentaría a nuestro favor la diferencia entre exportaciones e importaciones). En otras palabras, no solo habría aumento en la capacidad productiva y el empleo, sino que habría sustitución de importaciones, ayudando así a nuestra balanza comercial. Solamente asumiendo que nuestra producción bruta total aumentará (sobre los niveles de 1978) en un 2 por ciento, se generarían más de 20,000 empleos adicionales. Sin embargo, con toda probabilidad el aumento en capacidad productiva debido a una baja en los costos energéticos incrementaría nuestra producción en un porcentaje mucho mayor. Por el lado de la demanda, la disminución en la tasa de inflación incrementaría la demanda final por bienes y servicios y el ingreso real disponible de las familias. El aumento en la capacidad productiva, disminución en importaciones, aumento en ingreso personal y aumentos en la demanda final no hay la menor duda incrementaría los ingresos al erario público en una cantidad considerable. Solamente un aumento en la demanda final (doméstica) de 5% incrementaría la producción de $15006.4 millones a $15,710.9 millones (sobre los niveles de 1978), el empleo en unos 36,000 y los ingresos netos al fondo general del gobierno en unos $74.0 millones. Si el descubrimiento de una nueva fuente energética reduce los costos y aumenta la demanda final en un 9 por ciento, la producción aumentaría de $15,006.4 millones a $16,329.2 millones (a precios de 1972), lo cual incrementaría el empleo en unos 69,000 y el ingreso al erario público en aproximadamente unos $133.3 millones. La demanda final doméstica no incluye importaciones. El cálculo se hizo resolviendo el modelo de insumo-producto cuya ecuación es X =

(Ci-A) "En donde X es producción, (I-A) es la matriz inversa de Lentref y Fodenanda en el final doméstico. -6- ---Página Siguiente--- Estas cifras aproximadas le ofrecen una idea aproximada al señor Legislador de la importancia que tiene el asignar algunos fondos para 'Investigación y Desarrollo' en el campo energético que redunden en el descubrimiento de nuevas fuentes energéticas que abaraten los costos de producción y los precios de los bienes y servicios. -7-
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