CEER-X31 R&D PROGRAM NEEDS FOR ENERGY ALTERNATIVES. PUERTO RICO (June 1, 1979) PRELIMINARY REPORT - CENTER FOR ENERGY AND ENVIRONMENT RESEARCH - UNIVERSITY OF PUERTO RICO - US. DEPARTMENT OF ENERGY

CEER-X31 R&D PROGRAM NEEDS FOR ENERGY ALTERNATIVES, PUERTO RICO (June 1, 1979) PRELIMINARY REPORT

Number 3B LIST OF TABLES Description (Abbreviated) Reserved Estimates of Puerto Rico's Energy Requirements Schedule of Proposed Scenarios Program Objectives Possible Million Barrels Of Oil saved with scenarios Potential Energy and Cost Reduction Possible CEER Revenues from Fuels Tax and Law Total CEER Funds Requirements

CONTENTS

EXECUTIVE SUMMARY

The Center outlines its proposal 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 possible sources are analyzed. The unique position of CEER in ability to exploit the advantages inherent in the Puerto Rico site are 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. The conclusions are (1) Puerto Rico's energy crisis demands an expanded role by CEER in R&D which

The previous levels of funding and institutional relationships cannot be sustained. (2) With adequate funding, CHER 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

OTEC, Biomass, Photovoltaics, ethanol, and solar steam. (3) The scale of operations and funding level of CEER 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. The main recommendation is that an appropriately redefined role in R&D be assigned to the Center and that necessary funds be provided towards the goal of reaching energy independence or partial energy independence for Puerto Rico.

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 has necessitated the adoption of new strategies for conducting research and finding new funding sources. In these efforts, CHER has been quite successful. An examination of progress towards 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 to solve 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 investment of resources which may not have been considered possible previously.

Five years ago, the energy policy established in the public document of the Office of Energy, dated May 1979, indicated the priorities given to alternative energy sources, as shown in Graphic TII-1, page 46 (Appendix A of this document).

In line with this policy, the objectives of this document are:

(1) To present an assessment for energy independence or partial energy independence for Puerto Rico based on economical and state-of-the-art research, as well as the ongoing programs at the Center.

(2) To present the necessary budget estimates for the next decade on a year-by-year basis, outlining the funds required for a vigorous research and development program aimed at achieving partial energy independence.

(3) To recommend a strategy for seeking funding, which is most appropriate for achieving partial energy independence as soon as practicable.

(4) To highlight the necessity of providing self-sustaining and continuous funding to the Center for Energy and Environment Research (CEER) to address the massive research and development programs required.

The Center boasts forty-three scientists with an established reputation for productivity and responsiveness to the Department of Energy's (DOE) needs, especially in the areas of tropical ecology, nuclear research, education, and more recently, alternative energy source development. The research facilities, valued at twelve million dollars, are the best in the Caribbean. The FY 1979 budget amounts to approximately 3.5 million dollars, of which about 2.2 million represent base.

In line with this policy, the objectives of this document are:

(1) To present an assessment for energy independence or partial energy independence for Puerto Rico, based on an economical and state-of-the-art approach supported by the ongoing programs at the Center.

(2) To present the necessary budget estimates for the next decade on a year-by-year basis of the funds required for a vigorous research and development program.

The text should be corrected as follows:

The development program toward partial energy independence. (2) To recommend a strategy for seeking funding which is most appropriate for achieving partial energy independence as soon as practicable. (3) To bring attention to the necessity of providing self-sustaining and continuous funding to the Center for Energy and Environment Research (CEER) to address the massive research and development programs required.

II. 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.

Appendix C indicates the transition funding level of the Center. 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). The Center is presently involved in energy and environmental research projects within the total level of funding indicated. Such efforts have provided the Center's scientists and engineers with a deep insight and knowledge in the frontiers of alternative energy development.

The research projects include (1) Biomass Programs, (2) Ocean Thermal Energy Conversion (OTEC), (3) Direct conversion of solar energy into electricity through the use of photovoltaics, (4) production of steam for industrial uses, (5) fuel synthesis through fermentation processes - methane and ethanol. The funding and the level of effort is still too small for a meaningful address at the scale required for Puerto Rico's energy needs. The main bulk of the funding, approximately 2.5 million dollars.

The current contract's DOE-assigned funds are set to expire on October 1, 1981. The probability of extending the contract beyond this date is currently uncertain. Even if the present contract is extended, the level of funding will not be adequate to meaningfully address Puerto Rico's energy needs.

Future Projections of GEER Mission

The mission of CBER is to address energy and environmental questions that arise for the industrialized, tropical island of Puerto Rico in a way that is maximally applicable to other areas. Puerto Rico needs expert information to guide its orderly development. This development requires an objective assessment of energy alternatives in the context of their environmental and economic costs. CEER is the only institution on the island with the appropriate orientation, tradition, independence, reputation, and expertise to perform this necessary task.

Prospects for Competitive Funding

While DOE funding of relevant research is expected to continue, it will progressively become a smaller fraction of the total program needs. However, it is unrealistic to expect that the observed rate of increase in competitive funding can be sustained. There is a need for research in other areas for which CEER is the logical candidate, but the dollars available on the island are finite. Consequently, the Center will increasingly have to compete with other established research units for money from the United States and other sources.

This will require an increasing expenditure of effort on the part of the CEER staff. Little provision has been made for this contingency in CEER's structure to date. Using the national average for the rate of rejection of research proposals, it can be conservatively estimated that 1.3 man-years per year must be spent on grant proposal preparation to yield 1 million dollars of competitive funds.

Research to Secure Environmentally Acceptable Energy Alternatives

Vigorous efforts are underway to secure environmentally acceptable energy alternatives.

The text will be corrected as follows:

The solution to the specific energy and environmental problems for Puerto Rico will require significant effort. CEER is already involved in programs with the appropriate orientation, but a considerable amount of work will be necessary to solve the problems. Several cases can be cited as examples of the relevance and cost-effectiveness of CEER's current and planned R & D programs for the Commonwealth. OTEC, photovoltaic, biomass, ethanol, and solar steam are under consideration as alternative energy sources for Puerto Rico. In the Energy Policy public document dated May 1979, the Office of Energy assigns priorities to these alternatives. See Appendix A.

Taking OTEC as an example, plans call for a 40 MW plant generating about 1% of Puerto Rico's energy needs by 1985. A 250 MW Demonstration Plant will provide about 4% of energy requirements by 1990. There is also a potential 500 MW addition to the electrical generating capacity, bringing the OTEC total contribution to about 12% by the start of the 21st century.

For each of the energy alternatives, assumptions, costs, and environmental R & D considerations are discussed in more detail in Appendix D. The main points to emphasize are that the technology in question is cost-effective but needs to be adapted and expanded for Puerto Rico to make a reasoned approach towards energy independence.

For instance, Figure 1 illustrates the production cost of electricity from a 450 MW coal-fired power plant with Flue Gas Desulfurization (FGD) located at a site similar to Rincon, Puerto Rico under various assumptions, several of which are indicated on the graph. (Figure 1 was obtained from ongoing economic studies of energy alternatives being performed at CEER and will be published). The production cost indicated in mills/kWhr is a levelized value for the life of the plant, which has been estimated as 35 years. The x-axis indicates the year in which the plant begins operations. For comparative purposes, Figure 2 illustrates the same curve for the production cost of electricity.

From a coal plant, the level used (during a plant lifetime of 35 years) indicates the production cost of electricity for various types of plants. These include a 40 MW OTEC plant starting up in 1985, a 450 MW biomass direct-fired power plant starting up in 1987, a 250 MW OTEC plant starting up in 1993, and a 250 MW photovoltaic power plant with full energy storage to run at full power during nights and an additional 25% storage allowance for rainy or cloudy days. The details of these calculations are provided in Appendix D.

The summary of the example scenarios considered under a crash-type R&D Program heavily involving CER 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 an R&D Program in search of energy alternatives is functioning.

The fuel bill for Puerto Rico during the fiscal year 1979 exceeds one billion dollars, and the total bill for the rest of the century is estimated at approximately 156 billion dollars.

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

DEORE FOU ESTIMATED | YEAR | CONSUMPTION | INDUSTRY | TOTAL | UNIT PRICE | TOTAL COST ENERGY (1) | DIESEL(2)| OTHER(3) | WATT, | (IN MILLIONS)

1977 | 93.082 | 2.7 | 36.3 | 3977 | 93.082
1978 | 245 | 16.8 | 65.0 | 1979 | 26.0 | 1.0 | 25.11 | 6.1 | 170
1980 | 3900 | 27.5 | 2.3| 77 | 46.78 | 203 | 3361 | 29.01 | 18.5 | 77 | 959.17
1982 | 982 | 29.7 | 3.1 | 77.8 | 7130 | 1706 | 30.5 | 2.2 | 25.00 | 2055
1983 | 336 | 32.0 | 36.11 | 26.55 | 2458
1984 | 35.3 | 35.6 | 9.9 | 32.70 | 7939
1985 | 35.3 | 36.29 | 3380
1986 | 49.28 | 3903 | 188
1987 | 40.2 | 4633 | 3989 | 45.8 | 40.9 | 108.6
1988 | 49.60 | 5396 | 3980
1989 | 42.9 | 1113.9 | 35.00 | 266.
1990 | 30.81 | 51 | 19.9 | 58.75 | 744
1991 | 5308

1992 | 6275 | 756
1993 | 36.0 | 49.7 | 130.6 | 67.09 | 3285
1994 | 3996 | 3924 | 32.2 | 137.01

Column 6 of Table 1 refers to these calculations.

71.50, 3796, 1998 | 62, 6, 3a, 142.8 [76:50, Jose, 1996 | 65.0, 57-5, Bite, 12078, 1997 | 68.1, 60-8, 155.2 | 06-00, 13347, 1996-| 71-5, 63.4, 162-3 | 91.15, 14793, 1999, 7a, 66.6, 168.6. | 96.62, 16290, 2000, 77-6, 63.9, 1175.61, 102.6, 718016, TOT, 3155,829.

(1) Statistical correlations between population and GXP and between GNP and Electrical energy Generation. Correlation 99%. See Appendix.

(2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.6% actual. More accurate predictions to be included in Cuban Battery Studies.

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

(4) Fuel oil price escalation indicated is approximately 1980-85: 14.3%/year, 1985-90: 11% per year; 1990-95: 6.82/year and 1995-2000: 6% per year.

Table 3A 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 GUER is the main R&D researcher. The contents of the table are 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 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 dollars 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 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 tax proposed is based on...

"BTU consumption fluctuates between 1.5¢ to 2.5¢ per million BTU. A gallon of gasoline contains around 140,000 BTU, therefore, this would only add about 0.2-0.35 cents to a gallon of gasoline. A draft of such proposed legislation is included as Appendix B.

Table 3A: Schedule of Proposed Scenarios and Objectives

The following table will be organized in the period considered:

Table 3B: Possible Millions of Barrels Saved with Proposed Scenarios

1980: 1585
1985: 984
1995: 7956
2006: 2

Assumption: 60 kWh per ton of (S18 notation) bag.

Table 4: Example Scenarios Table and Potential Energy and Cost Reductions

1986: 93.4
1987: 96.9
1988: 703.6
1989: 9019.8
1993: 0.8
1995: 137.0
1998: 162.3
2000: 175.6
2005: 6.6
Total: 2072.0

Table 5: Possible User Revenues from Fuels Tax Reduction

Scenarios: 0.00
Amount: 71.70
Fee: 6.45
Tax: 0.55

Table 6 illustrates the total funding requirements for the illustrative scenarios. The last two columns of Table 6 indicate the suggested source of funding. Column 13, labeled "Base Funding Requirements" in Table 6, shows 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 table."

The indicated discussion column, this is explained 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. CEER is the only agent on the Island capable of and already involved in such work for Puerto Rico. CEER will not be able without assurances of base funding to continue this leadership role.

FUNDING ALTERNATIVE – THE BASIC PROBLEMS Legislative Appropriation Various alternatives of 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's 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 $5-18 million dollars annually. A very low probability of success was given to this alternative.

(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 with revenues to the state of its gross to the General Fund. However, recent amendments have committed fully this contribution in relation with 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 on the level of $5-18 million (The Rum Pilot Plant legislative fund allocation 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. Appendix B describes the proposed legislation. This is considered the most logical alternative. V. Conclusions: Puerto Rico's energy crisis demands an expanded role by CEER in R&D which previous levels of funding and institutional relationships cannot sustain.

1. With adequate funding, CEER 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 OTEC, Biomass, Photovoltaics, Ethanol, and Solar Steam.

2. The scale of operations and funding level until now were adequate for transition from the Puerto Rico Nuclear Center to the founding of CEER. They are not adequate for performing the research and development role in Puerto Rico's energy crisis.

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

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

VI. Recommendations:

1. It is recommended (1) that the appropriately redefined role in R&D be assigned to the Center and that necessary funds be provided, (2) that proposed legislation on funding receive adequate endorsement.

(A) Unreadable text

Fig. Alternative Energy Sources Production Costs

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The Center was established by the U.S. Atomic Energy Commission in 1957. The Nuclear Center was operated by the University of Puerto Rico 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 has under study or development more than forty (40) principal projects related to energy conversion and conservation.

The current energy crisis, which is caused by a world 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 anomalous 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 undertaking some projects in this respect using the funds allocated first by the ERDA and now by the Department of Energy, using the present available facilities which are capitalized at approximately twelve million dollars ($12,000,000). These facilities are being transferred to the University of Puerto Rico by the Department of Energy (DOE). CEER has been operated by the U.P.R. under contract with DOE, in which the latter funds all the operational costs while also allocating additional money grants for individual projects on a competitive basis. These projects are for the development of energy from natural resources and also for the protection of the environment.

On September 30, 1981, the contract expires and thereafter, DOE will not cover the operational costs of the CEER. Although the

Funds obtained from grants on a competitive basis will not continue, hence, they will not be enough to cover all the expenses. It is necessary that the Legislature appropriates the required funds to cover the Center for Energy and Environment Research (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, be it enacted by the Legislature of Puerto Rico:

1. It is hereby found and declared that the purposes of the CEER of the University of Puerto Rico are the development of environmentally acceptable energy alternatives through research on new fuels to substitute those made from petroleum, and research to understand and protect the ecology and natural resources of the Island. These objectives are public purposes in all respects for the

benefit of the Commonwealth of Puerto Rico.

2. The programs already started should continue, and new projects and grants sought for research and development are already established. Due to this, it is necessary that the Legislature appropriates the required funds to continue the same.

3. The sum to be appropriated every year should be obtained by levying taxes on all types of fuels, crude, refined, or a combination of both, that enter into the Commonwealth of Puerto Rico as specified here.

4. Taxes to be levied shall 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.

5. The Secretary of the Treasury of the Commonwealth of Puerto Rico is authorized and directed to collect the mentioned taxes and to place the sum collected at the disposal of the Director of the CEER starting July 1, 1981.

6. All laws or parts of laws in conflict herewith are hereby repealed.

7. This Act shall continue.

This will take effect ninety (90) days after its approval.

SAAR AS 008 ° PPRMOTOH0G °

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX D EXAMPLES OF ALTERNATIVE SCENARIOS

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, UNIVERSITY OF PUERTO RICO

THE ENERGY PROBLEM IN PUERTO RICO

Various efforts are being undertaken by a variety of organizations in the Puerto Rico Government in the pursuit of solutions to the 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 is not under one option, but on 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 life. Therefore, it is felt that an aggressive energy program with definite goals and objectives should be developed and pursued to bring forth solutions as soon as possible but with known and calculated acceptable risks. CER 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 energy generation at present. This does not include technological developments which

Will tend to use more electrical energy such as the electric cars which are now being introduced in the world markets. Appendix "Long Range Forecast of Energy Needs in

Puerto Rico: This describes the model used for predictions. This appendix is part of an energy study being performed by CEER. The growth in electrical generation indicates that the Puerto Rico electrical system will need to add roughly twice the actual generation capacity before the year 2000 in order to maintain approximately the same level of economic welfare. This statement, under the current serious prediction of increasing fossil fuel costs and scarcity of fuel oils, is rather alarming. An aggressive program to address the massive amounts of electrical energy generation requirements of Puerto Rico is required as soon as possible.

CEER PROPOSED PROGRAM: In order to positively address the energy situation, CEER proposes, as an example, a strong R & D program on the following alternatives: Ethanol (Motor Fuels) and Solar Steam. Specific objectives are set for each of these alternatives with approximate start of operation dates and schedules of required R & D funds.

Each alternative is economically evaluated in the Puerto Rico energy scenario. From the economic and technological potential and the present state of development and the interest of the federal government, various approaches which might be acceptable by the organizations concerned are developed. The summaries of the scenarios considered, under a crash type R & D Program heavily involving CEER, are shown in Tables ? to 06. The following traces out the salient points of the overall proposal. Appropriate details are presented later in this appendix.

Table 2 indicates an approximate prediction of the energy requirements in Puerto Rico up to the year 2000. Under the present socio-economic structure and without a strong R and D program on alternate energy sources, the fuel bill for Puerto Rico during the present 1979 year exceeds one billion dollars and the total bill for the rest of the century is estimated at 155.829 billion dollars.

Table 3A presents the mentioned example program of energy alternative objectives under a very tight schedule.

The following text can be fixed as:

It is only achievable by a concentrated and coordinated effort between various government energy planning-related organizations in which CEER is the main R&D researcher. Table 3B indicates the barrels of oil saved by the proposed trash program example scenarios. Table 4 illustrates the effect of the example energy alternative scenarios proposed in the total fuel oil consumption of Puerto Rico. A reduction of nearly 52,000 million dollars equivalent to ~30.

TABLE 2 ESTIMATES OF PUERTO RICO'S ENERGY REQUIREMENTS TO THE YEAR 2000

UNDER PRESENT SOCIO-ECONOMIC STRUCTURES AND ABSENCE OF STRONG HAND PROGRAM ON ALTERNATE ENERGY SOURCES.

(1) Statistical correlations between population and XP and between GRP and Electrical Energy Generation. Correlation 0.998. See appendix.
(2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.68 actual. More accurate predictions to be included in CEER Energy Studies.
(3) Industrial needs projected at 5% per year growth. More accurate predictions to be included in CEER Energy Studies.
(4) Fuel oil price escalation indicated is approximately 1980-85: 14.3%/year, 1985-90: "LIE year".

Note: The numbers in the text lack context, hence it is not clear what they refer to, so they have been omitted in the revision.

1990-95: 6.82 per year and 1995-2000: 6% per year.

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Again, there appears to be a substantial amount of illegible text, which I cannot correct without further context.

Table & Potential, Energy and Cost Reduction: Example Scenarios
Note: The following table contains a significant amount of unreadable data that I am unable to correct without further information.

36% of the total dollar expenditures up to the year 2000 are accomplished by the example scenarios. This high figure is probably the maximum saving which could be achieved since it is predicated under a very tight schedule and R&D crash program 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 environmental research and development is proposed on all non-renewable fuel consumption in Puerto Rico. The tax proposed is based on BTU consumption and it fluctuates between 1.5c to 2.5c per million BTU. A gallon of gasoline contains approximately 140,000 BTU.

"Therefore, this would only increase the cost of a gallon of gasoline by 0.2 ~ 0.35 cents. Table 6 illustrates the total CEER fund requirements for the given scenarios. The last two columns of Table 6 indicate the suggested sources of funding.

TABLE: POSSIBLE CEER REVENUES FROM FUELS TAX RED LAW

(Welton [156/70])

Year	Barrels (k)	Tax a year	Consumption with tax

1980	71.70	6.45	0.53
1981	75.20	6.77	0.47
1982	77.80	3.3	4.98
1983	82.70	2.6	1.96
1984	66.10	7.1	5.39
1985	69.57	13.40	0.73
1986	87.76	73.18	0.71
1987	65.96	12.09	0.37
1988	85.53	12.83	9.89
1989	25.40	12.81	3.0
1990	42.02	2.7	1.99
1991	12.93	23.6	13.92
1992	1.1	0.795	33.35
1993	73.92	2	1.995
1994	13.48	20	1.996
1995	13.32	16	3.997
1996	33.32	7	13.98
1997	13.34	16	7.999
1998	13.29	6	7.2000
1999	1.0	15	0.36

The logic in selecting and setting the example scenarios has been based on the information, experience, and knowledge generated from R and D programs undertaken by CEER since 1976. The level of effort has been very low, at the level of 2-3 million dollars per year, 100% funded by the Federal Department of Energy. This low level of effort needs to be increased significantly, as has been indicated, in order to produce meaningful results. Economic considerations and evaluations, potential capacity of the alternatives to meet local energy needs, and the 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 meet all of Puerto Rico's energy needs in the future. Ocean-based or floating types of plants in the southern Caribbean Sea would have little to no impact on land utilization resources. It's estimated that an OTEC-10 (40 MW plant) concept could be operational within 4 years. Preliminary economic calculations under certain circumstances indicate that this could be feasible."

The project indicates that the energy costs will be 48% of the cost of a 450 MW coal plant, without the steam cogeneration portion. The economic attractiveness is even higher when the steam portion is added. These costs were determined for the P.R. scenario by using higher costs than the most recent basic data cost information. RED funds need to be secured by CEER from the Puerto Rico Government for this project at a level of $40 million, excluding advance concept developments. It is assumed that the Federal Government will match these funds for a total of $80 million requirements in RED. A consortium of private enterprises, PRWRA and Fomento, is suggested for the capital investment.

The biomass - Biomass is practically an agricultural enterprise that consists of planning 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 for 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 50,000-60,000 acres of land will be required to feed the plant.

By Solar Electricity and Economic Approach to Solar Energy-Wolfgang Palz, Commission of European Communities.

The principal and immediate objective in a biomass program will be 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 kW electrical boiler and is large enough for extrapolation to 400-500 MW boiler. The economic analysis indicates that biomass is the costliest of the three.

Alternatives, but still has a good economical advantage over the coal alternative. The preliminary calculation indicated that the cost of electricity from biomass is 86% of the cost of electricity from a 450 MW 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 PRWRA 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, such 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 estimated conservatively at one billion gallons of gasoline (equivalent to 1.67 billion gallons of ethanol). This could be produced with a program requiring 1,000,000 acres of sugarcane plantation, which is approximately 89% of the agricultural land in Puerto Rico. Costs are estimated to be competitive. The R&D program objectives include the modification of a sugar mill to process 4,000 tons of green sugarcane per day to produce approximately 6,000 gallons per day of ethanol and the extrapolation of the experience to a larger industrial scale to produce 11% of the gasoline requirements by the year 1990. The indicated objectives are based on approval this year of planned pilot plant operations at the UPR-RIM Experimental.

Station and existing programs of development of Saccharum hybrid species for increased yields. The total R&D funds requirements 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 Li 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 the energy requirements) by supplying at least 40% of the steam 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 are $25 million, excluding the development of advanced concepts and related material development.

Total Budget: The total R&D budget which will be required by CEER from the Puerto Rico Government to aggressively attack 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

Content:

This plant can generate 7% of Puerto Rico's energy needs by the year 1990.

1. Electrical System Addition on a Competitive Basis: The first 500 MW OTEC Plant was in operation by the year 1995 and an additional 500 MW OTEC unit was added 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.

2. 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 (40,000 MW x $5,000/MW) = $200,000,000
b. Yearly Investment charges at 10% cost of money = $20,000,000
c. Yearly energy production 298 x 10^8 kWh at 85% capacity factor
d. Investment charges in mills/ 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 take the same amount of manpower as the two (450 MW each) oil fuel Aguirre Units, this would amount to approximately a staff of 170 men. At an average salary of $24,000 per man (PHBA average salary for power plants), the total staff cost is as follows:

Total Staff Salary: 170 x $24,000 = $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 GEER Studies to be 2.33. Using the same ratio, the total O&M cost is:

Total O&M = (2.33 x $4,080,000) = $9,506,000
O&M costs in mills/kWh = 31.9

3. Fuel Costs: The fuel costs are estimated to be 0.0.

Total costs are yet to be calculated.

Demonstration Project - 99.0 mills/kwhr 1978 dollars 1985 Total levelized costs. This cost can be estimated by including escalation and interest during construction and levelizing the O&M escalation cost during the plant's lifetime. Assuming 7% per year, one year period planning, and contracting arrangements, 2 years design, and 3 years construction, the interest during construction and escalation factors can be worked out as follows (Assuming a straight line cash flow of construction funds). For escalation and interest during construction considerations as well as levelizing considerations, cost of money, etc. see ARERR TER REREE Sed MOBY HO SERSEL by Sommer HALTY.

Planning Design:

1979, 1980, 1982, 1985

Escalation before construction = (1.07)

Escalation during construction = (1.07)^2.5

Interest during construction = (1.07)^1.5

Investment, Escalation, and Interest during construction. Total Factor = 15.

Operation Escalation at 7% per year between 1979 and 1985 = (1.07)^6 = 1.5

Levelizing factor for 35 years lifetime at 10% cost of money in a 5% inflationary economy yields a levelizing factor of 1.75. Total levelized cost 1985 Investment charges: = 100.65 (67.1) (2.5) Operation and maintenance (31.9) (1.5) = 1.75

Plant total levels 104.3 mills.

Figures 1 and 2 indicate the relative cost. For Escalation and interest during construction considerations as well as levelizing considerations, cost of money, etc. see separate CEER studies (Baseline costs of commercially available energy alternatives in P.R. scenarios).

Comparative Costs:

The above cost can be compared with 92.5 mills/kwhr for a single 450 MW coal plant at Rincon with flue gas desulfurization, 35 years lifetime and operating at 75% capacity factor (the lower capacity factor is justified in an economic dispatch competition). Figures 1 and 2 indicate the production cost. 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.

The costs are 92.5 mills/kWh (total lifetime 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 PRARA (or $17.4 million in terms of 1978-79 dollars). For the RSD 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: *CBER Studies on Baseline Costs of Commercially Available Energy Alternatives. The cost quoted needs revision for cooling water system acceptable alternative.

Investment in terms of 1985 dollars:
PRARA $26.2 million ~ (plant investment)
PR Gov $26.2 million ~ (R&D)
Fed Gov $247.6 million ~ (plant investment plus R&D)
Total $300 million

The funds assigned by the Puerto Rico Government should be mainly for R&D, infrastructure, facilities, laboratories, and operational R&D.

Approximate Cash Flow of Funds for Demo Project:

PR Gov, PRERA, DOE
Year | Year Cumulative | Year Cumulative| Year Cumulative
79 | - | 180 | 2 | 2 | 102 | 16 | 83 | 10 | 82 | 38 | 102 | 30 | 83 | 16 | 202 | 20% | 60 | 83 | 85, 22 | 300% | 40% | 100 | 100

The contribution to OTEC from the Puerto Rico Government in terms of dollars should be:

Year	1980	1981	1982	1983	1984	1985
Total	$3.1	$3.97	$3.93	$4.09	$5.24	$5.86

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. PRERA can share a higher risk and the Government also.

It is expected that each plant would cost $1500/kw in terms of 1978 dollars.

The cost of such a plant would be:

Investment charges: 2300 x (21) x 20.1 units x 8760 x C5. The cost would be in terms of 1990 dollars (with 4 = 39.5 mills). Operational and maintenance costs will be double the construction cost, assumed to be twice the staff cost (1978 (9,506,000) x 2 = $19,012,000). The levelized 1990 dollar cost will be (20.2) x (2.25) x (2.75) = 40.2 mills/kwhr. The total cost is 80 mills/kwhr. This cost is much lower than a fossil plant. PRWRA can finance it completely.

B. Risk Analysis Considerations (of Demonstration Plant of Objective No. 1)

Since PRWRA 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 PRWRA in the preliminary economic analysis presented here is 8.733% of the total funds.

Feasibility Design Studies: Deep Oil Technology Inc. Subsidiary 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 correlation between risk and investment, then we can assume that if the chances of success of OTEC are better than 8.733/100, the PRWRA 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 PRWRA, is taking an acceptable risk. It is promoting a needed energy alternative which will be multiplied by various orders in additional revenues. CEER studies under consideration will quantify this benefit for Puerto Rico Treasury and the general welfare. Puerto Rico will be taking a 17.46/100 combined risk and the Federal Government the balance. We feel that more refined calculation in risk analysis and project co-sharing should be pursued.

Worked out with more time and funds availability to CEER.

F. Advanced OT8¢ Concepts

After the first OTEC plants become operational, R&D funds need to be secured for improvement of the existing embryonic technology and for technical problems which might arise. The foam ORC concept being investigated by CEER should then receive more detailed consideration. A yearly allocation of $1.0 million dollars (in 1979 value) should be allocated for these purposes from 1986 onwards. With an 8% escalation beginning in 1979, the following escalated allocations are computed.

ADVANCED OTEC CONCEPT FUNDING (IN MILLIONS): 1986, 1987, 1988, 1989, 1990

G. OTEC Environmental Research Scenario

The primary environmental issues associated with OTEC appear to be:

1. Heat exchanger design
2. Intake design
3. Discharge design
4. Working fluid design
5. General unit configuration

All the above impact upon 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 Table 1. It is assumed that the funds for environmental research are included within the allocations already mentioned.

TABLE 1 OTEC ENVIRONMENTAL PROJECT

CEEC ENVIRONMENTAL ECONOMIC/AESTHETIC CONSIDERATIONS

TECHNOLOGY DEVELOPMENT NEEDED

1. Heat Exchanger Design:
   - Biofouling
   - Potential of different configurations, materials and modes of operation
   - Toxicity of control treatment
   - Fouling influences efficiency, control methods cost
   - Potential reduction in fisheries

2. Intake Design:
   - Impingement potential
   - Entrainment potential
   - Obstruction reduces efficiency
   - Potential reduction of biotic stocks, reduction of fisheries

3. Discharge Design:

- Field effects of different configurations and operations
- Influence on currents
- Influence on elemental distribution
- Influence on temperature
- Redistribution of plankton, reorientation of fish
- Alteration of primary productivity-Food chain
- Alterations leading to alterations in

Fisheries: Bioaccumulation of heavy metals in food chains leading to humans.
4. Working Fluid Design: Field effects of leakage such as acute chronic direct human injury, direct kill of organisms, toxic or stimulatory effects resulting in shifts of communities, losses of economic species, and losses of aesthetically important forms impact on tourism.

I. Photovoltaics AL Program Objectives:
Small scale demonstration (162 KW) project to be located at CEER. This small project will provide know-how to deal with this new technology and will develop greatly needed human resources to tackle larger projects. Project operational by mid 1980. Data gathering thereafter.

II. Electric Power:
Installation in the higher insolation areas of Southwestern Puerto Rico to provide 250 MW Photovoltaic installation by the year 1993 and an addition of 250 MW photovoltaic plant capacity by the year 1993.

III. A Cogeneration Project:
To develop power and steam in an industrial park with the photovoltaic plants.

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 1 KW plant peak capacity for 8 hours to deliver to the load 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. This provides an emergency “spinning” reserve of three times the continuous rate capacity of the photovoltaic installation for the electric utility, since the storage system can be discharged at the same rate as its charging rate. Credit

"For the extra inning,” reserve capacity can be credited at the rate of the capital cost of a conventional gas turbine. To take care of the absence of solar radiation during rainy days, overcast skies, and storage system maintenance problems, a 25% additional energy storage will be provided. At an efficiency of collection and production of 4.5% and an average insolation power of 7

KW-hr per square meter per day, the required area for producing 1 KW of continuous power is: 3x = 76.2 a -38-

The average insolation power per square meter is 1/24 or .292 kw per sq. m. per 24-hour day.

2. Investment costs

The cost of a photovoltaic installation can be approximated by the following relationship: Plant cost ($) = array cost /a2 + Power Conditioning Cost ($) + 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: Solar cell cost = a) 1.0 mill/em2 or $10.00/m2; Wiring, structure, installation cost/m2 = $10.00/m2. Total array cost: $20.00/m2

(3) Storage cost per kWh: $25

(4) Power conditioning cost per kWh: $50

Plant Cost: 20 + (1.25)(25) + 16 + 50 (0.45) (0.292) = $1522 + $500 + $50 = $2072/kw

A $200/kw could be credited due to twice availability. This cost is similar to the one predicted by Unesco.

(3) Costs of $20.00 per kW-hr are predicted by Unesco. "Solar electricity and economic approach to solar energy - Wolfgang Pätz, energy development program, European Communities Brussels," UNESCO 1978.

3. Land and land rights charges:

The area for the plant (at a rate of 76.2 m2 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.

Total Plant Cost:

Plant: (250,000) (2072) = 9518 x 108

Land: 5,000 acres at 2000 = 10 x 108

Total: 328 x 107

Investment charges in mills/kW-hr. 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 feel...

The text is suggesting that an annual three-week outage for photovoltaic maintenance is sufficient, resulting in a 94% capacity factor. The investment cost, considering a 10% cost of money and a 94% capacity factor, would be significant. This calculation is based on 1977 dollar values.

The costs of operation and maintenance (O&M) will be determined by the plant staff. The size of the plant will require a large staff, including a variety of roles from superintendents to security personnel.

The total staff count is 93 with an average salary of $24,000 per individual. The total salary expense is $2,232,000. Assuming a factor of 1.0 for material replacement, the total annual O&M cost is $4,464,000. This equates to 2.1 mills/kwh, for a total cost of 27.1 mills/kwh in 1978 dollars.

The text then goes on to adjust these costs for inflation up to 1993, accounting for the five-year construction period. The escalation factor for investment is 2.33 and for salaries, it is 2.76. The levelizing factor for plant life escalation of O&M is 1.75.

The investment cost becomes 60.6 mills/kwh, and the operation cost is 70.7 mills/kwh. The cost of an equivalent coal plant is cited as 148 mills/kwh.

Please note that the text is quite hard to follow due to numerous spelling and grammatical errors. The corrected version above retains the original meaning, but the language has been significantly clarified and corrected.

The cost of energy for the photovoltaic concept is 48% of the cost of a 450 ton coal plant. The project should be suitable for commercial financing. The cost of the plant itself, estimated at $2072/kw, can be the same or higher in cost and still the plant will be competitive with coal. Figures 1 and 2 indicate production costs for the Photovoltaic Cogeneration Project 1. The economics of photovoltaics looks very promising in the P.R. scenario. Since a photovoltaic installation requires 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 waste heat of the solar collectors and backed up with oil-fired boilers or biomass-fired boilers during the night hours. Such a system offers great economical 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 level of R&D funds requirement only)

About 4 KW thermal power is produced for every 1.00 KW produced in the CEER 150 KWS cogeneration project under consideration. A steam flow of 2,122 lbs/hr. at 220°F with an enthalpy of 765 BTU/lb is predicted along with an output of 151 KW. There is no condensate return in the CEER project. For a large cogeneration project, condensate will have to be returned. Assuming 100°F condensate (obtainable with seawater once through condenser) the amount of heat that can be extracted is approximately 900 BTU/lb 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 cogeneration project of 250,000 KW will be 3.15x109 BTU/hr. (Note that the

250,000 KW is the average 24 hr. daily generation. The plant peak power... [text cut off]

The capacity is three times higher at approximately 64 and it stores all the 24-hour energy in the assumed 8 hours of daylight. At a 60% capacity factor of the steam portion, the yearly generation in thermal heat is 2.2 x 10^13 Btu per year. Figuring conservatively at $2.00 per MBtu steam cost for a competitive project, total gross yearly revenues are $44 million. The level of investment for the cogeneration project 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 significantly lower than from an oil-fired plant, the project can be funded by financial enterprises on a commercial venture with FRARA, Fomento, and the PR Government. The project could be in operation by 1991-1992. It is assumed that the PR Government can contribute 50% of R&D funds, with the Federal Government contributing the remaining 50%. PR Government's assignment to this project is at a level of $25 million (1979 basis).

The funding distribution is estimated as follows for Research Funds for Photovoltaic Cogeneration:
1979 - $10 million
1980 - $5.6 million
1981 - $81 million
1982 - $1.26 million
1983 - $13.6 million
1984 - $1.59 million
1985 - Unspecified
1986 - $7.4 million
1987 - $4 million
1988 - $1.62 million
1989 - $40.73 million

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 one million dollars yearly (1979 basis) beginning in 1987. When escalation is figured at 8% per year from the base year 1979, the following is the net result:

Advanced Photovoltaics Concept Funding (in $ Millions):
1987 - $1.85 million
1988 - $2 million
1989 - $2.16 million
1990 - $2.33 million

Environmental Research Scenarios for Solar Photovoltaics:
The primary environmental questions arising...

The benefits derived from this technology have to do with two main aspects: 1. Site selection, considering the 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.

Page Break

Section A. Program Objectives (In addition to the actual program of species identification and production optimization) + Design, construction, and operation of a pilot boiler plant with a capacity of 1000 tons of biomass fuel per day, achievable by modifying an existing sugar mill. The project can be operational within 12 months after initial authorization, including the collaboration of the PR Department of Agriculture and the Sugar Corporation. The boiler size is comparable with a 62,500 kW electrical power plant boiler and is considered large enough for a seven-fold extrapolation to an acceptable 450 MW boiler plant. The RRA should 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. Routine considerations to be given by PRNRA, under available technological know-how and market conditions, for evaluation of biomass on a competitive basis with other available alternatives for the future electric system.

Page Break

Section B. Biomass Economics in Additions Beyond Year 1990, Scenarios Pilot Boiler Plant: It is estimated that a two-year project demonstrating a

The pilot bioenergy plant, with a capacity of 1000 tons per day and operational on a 12-month basis, will cost approximately $2.5 million for sugar mill modification and logistics considerations. Additionally, $400,000 will be required for one year of operation and data gathering. About 1/3 of the investment will be in the biomass production phase, with special emphasis on off-season biomass production during a four-month interval when bagasse will not be available.

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

The Department of Agriculture's budget is estimated at $512,000, and the total production costs amount to $1,142,000. With the inclusion 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 will 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. Costs and logistics of biomass delivery technology
d. Furnace performance and design

Since the pilot project cannot be evaluated on a competitive economic basis, its costs will be added to those of a commercial project identified under program objective No. 2.

For the Large-Scale Plant Project, calculations for a 450 MW plant will be made in terms of 1987 dollars and will be compared with a similar coal-fired unit.

The cost of the power plant to burn coal and biomass are as follows:
a. Investment charges: Coal Plant: $683/kw (1978 dollars)
b. Biomass plant: A credit of $29/net kW can be given to the biomass plant for unneeded equipment to burn no-sulfur fuel, but additional requirements will be necessary to burn both coal and biomass.

Biomass and coal can be burned in the same boiler. It is assumed that the costs of these two processes cancel each other out. The cost of running a biomass-burning plant is assumed to be the same as operating a coal plant.

The cost of a biomass power plant is $683/kw (in 1978 dollars). Investment charges for a coal plant (in 1985 dollars) is 23.2 mills per kWh. After adjusting for inflation to 1987, the cost increases to 27 mills per kWh.

Fuel Costs: The fuel costs for biomass have been calculated at $25 per ton delivered, with a heat content of 15,000 BTU per ton. This equates to $1.66 per million BTU of delivered fuel cost (information courtesy of Alex Alexander). This cost is based on 1979 fuel prices.

Assuming the same carrying charges for a biomass stock storage of 3 months as was assumed for coal, the carrying charges for biomass are 1/4 (1.66) (.1) or 4 cents per million BTU. Therefore, the fuel costs at 1979 dollar level is $1.70 per BTU, including 3 months stock storage charges.

This includes a production cost of $19.00 per ton and $6/ton transportation costs. Drying of biomass will be done in the field, and bales or bundles are truck transported from the field to the power plant storage pile.

Levelized fuel cost in 1987 dollars, with 7 1/4 % escalation, is calculated as follows:

1987 Fuel Cost = (1.70) $(1.0725)^n$

Levelized (over 35 years) cost = 1.75 (2-97)=95.20 per BTU. With a plant heat rate of 10,000 BTU/kWhr (at 75% capacity factor), the levelized fuel cost is 52 mills per kWhr.

The operation and maintenance of the biomass operation are assumed to be equal to that of a coal plant, minus the operation maintenance of a Flue-Gas Desulfurization (FGD) System. The estimated cost for Operations and Maintenance (O&M) of a Desulfurization System for a coal plant is calculated as STR (47) + 10Pqq (LF) $(1 + c)^n$, where:

- S = sulfur content of coal 2/100
- P, = price of Limestone $/ton
- TR = coal firing rate tons/hr

- Pqq = price of sludge disposal $/ton
- LF = plant coal factor
- e = escalation
- Y = years between time of estimate and beginning

This takes into account the rising costs during the plant's life.

Note: 1 ton of sulfur requires 4 tons of Limestone to produce 5 tons of sludge. This is combined with 5 tons of water to produce 10 tons of sludge.

Wet sludge, which requires disposal.

Using the same figures as for the coal CEER plant study:

PL = Pyd = $5.50/ton

ß = .03

Tr = 200 tons/ar.

LP = 75%

Y= 7 years

e = .08

Substituting the above figures into the formula gives,

OM Desulfurization Plant = $5.2 x 10^8/year

The equivalent OM cost in mills/kwh for FGD system is 1.91 mills/kwh.

The levelized 35 years OM for FGD System is 3.35 mills.

The total O&M levelized cost for a coal plant has been determined at 12.0 mills/kwh (1985 cost)

1987 cost = 13.7 mills/kwh.

Coal plant gross capacity is 450,000 kw. Net capacity will be 424,000 kw.

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

Total cost for Biomass plant 35 years levelized cost in dollars is:

Investment (same as coal plant)

Fuel OM

Total (Biomass fired plant cost)

The comparable cost for a coal plant is 92.7 mills/kwh.

The 92.7 mills/kwh is corrected for the investment of 6.00 million (escalated) research funds invested in objective number one. The correction is rather small. This corresponds to .000357 mills/hr.

The R&D funds will be more than recoverable in the program. In addition, 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 objective of the program can stand on its own economical basis.

Figures 1 and 2 indicate product C.

Energy Research Funds Requirements for Biomass:

1979 1980 1981 1982 1983 1984 1985

1979 Base 2.0

Escalation 1.0 1.08

Actual 2.26 0.59 0.50 0.54 58.64

Late revision by Dr. A. G. Alexander indicates small additional total funding requirements in the order of $930,000.

ZB is the possibility: Advanced

Biomass Programs: For the development of advanced programs such as fluidized bed systems, pelletizing, and cycle improvements, technical difficulties of developed methods require improvements. A yearly assignment of 3/4 million in 1986 and 91 million thereafter is allocated (1979 basis). When escalated at 8% per year, the result is:

ADVANCED BIOMASS PROGRAM DEVELOPMENT (MILLIONS $):
1985 - 1.85
1987 - 2.0
1988 - 2.36
1989 - 2.33

Biomass Scenario: 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 a soil amendment.

Secondary environmental research should be pursued, such as coupling sewage and other waste disposal to biomass production to alleviate the fossil fuel subsidy required for high biomass yields. Biomass production requires land, and site selection needs to consider 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 the biomass program. However, it's 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 currently increasing at a rate of 6.62% annually over the last twelve (12) years (1966-1978). Ethanol, which could be produced from sugar cane as a motor fuel substitute, will be competitively priced with gasoline by the time a project to produce and market ethanol can become a reality. Predicted costs of ethanol are in the range of $1.00 to $1.25 per gallon. The equipment and facilities required for this exist in Puerto Rico and would require relatively small investments for conversion. Cane juice is extracted by conventional sugar cane methods.

During the process, juice is clarified in existing sugar. This will involve the data from the Office of Therapy (2) and sugar crops as a source of fuels - DOE - 1978 -76.

The process involves clarifiers and rotary vacuum cleaners. The juice is concentrated to about 20% total sugar content. From this step onwards, a modification is required to the sugar mill. This modification involves yeast fermentation of the concentrated juices. The fermentation can last 12-18 hours and is followed by distillation.

The cost of these additions is approximately 10-15% of the investment cost of a sugar mill. In the sugar industry, bad weather or rain can be disastrous to the sugar sucrose yield, reducing the revenues of the farmers. However, this does not affect alcohol production, and on the contrary, it can be an asset.

The production of ethanol from sugar cane and electricity from sugar cane bagasse, combined with the utilization of cane wastes, is a very attractive program. Currently, ethanol yields from sugar cane are 15.6 gallons per ton of green sugar cane. The average production of sugar cane in Puerto Rico is approximately 28 tons per acre. Alexander (1) has estimated that with a program partially optimized for biomass, yields as high as 29 tons of dry biomass (216 green tons per acre) are obtainable. The ethanol yield would then be 1800 gallons per acre.

Historically, experience has shown that yields under actual field conditions are much lower than those achieved under controlled experimental conditions. Therefore, it is logical to expect a lower yield of ethanol per acre.

For the purposes 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. To produce the same number of gallons of ethanol as 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...

(1) The potential of sugar cane as a Renewable Energy Source for Developing Tropical Nations - A. G. Alexander.

This will be equivalent to only 60% of gasoline requirements. In addition, this plantation could produce the total energy requirements for the ethanol plant and generate 50% of all the electricity requirements for the year 1982 by burning 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 very 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 economic evaluation of a project to produce ethanol and bioass for electricity.

B. 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 of 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 R&D funds. This project is to function in parallel with the biomass boiler project requiring 1000 tons of dry biomass (4000 green tons) per day. The project will be operational by the year 1983.

4. Large Scale Operation - Goal for 1986: Ethanol production to equal 11% of 1990 gasoline requirements. Investment cost for a new facility (optimized) is $225 million. The cost could be reduced if the assumed growth rate is reduced from the present 6.6% per year to 3.3% per year. 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.

The cost is projected to be $60-105 million if existing sugar mills are considered. Economic studies of both alternatives are required. Additionally, optimization studies of ethanol for electric energy and electric cars scenarios need to be examined against ethanol for cars.

b. Electrical generation with bagasse is enough to feed 50% of the fuel requirements of a 500% 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, or $325 million. It was shown that the alternative of direct firing of ash 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 Funds 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:

ETHANOL R&D PROGRAM FUNDS REQUIREMENTS (1979)

Year - Factor - Millions - Escalation - Actual

1980 - 50 - 1.08 - 34

1981 - 1.00 - Lay - Lay

1982 - 1.00 - 1.26 - 1.26

1983 - 1.50 - 1.36 - 2.04

1984 - 1.50 - 1.47 - 2.21

1985 - 1.00 - 1.59 - 1.9

1986 - 0.75 - unknown - 1.28

1987 - 0.50 - 1.85 - 93

1988 - 0.25 - 2.00 - 50

1989 - 0.25 - 2.16 - 36

1990 - 0.25 - 2.33 - 58

Total - 8.50 - 12.64

D. Advanced Concepts for Ethanol Research

Research for the production of ethanol at lower costs includes increasing yield production, new methods of fermentation and distillation, and new cycle optimization methods. Improvement of technical difficulties of the first ethanol plants will also require research funds. For these purposes, $0.25 million is assigned for 1985, $0.8 million for 1986, $1 million for 1987 and 1988, and $1.5 million for 1989 and 1990 (in 1979 dollars).

After escalating the indicated allocations, the following results:

ADVANCED CONCEPT ETHANOL FUND REQUIREMENTS (ESCALATED)

Millions: 985 (1986), 1987, 1988, 1989, 1990 - 0.86, 1.85, 2.0, 3.24, 3.5 respectively.

Title: Environmental Research Scenario for Ethanol

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

Title: Solar Steam 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 in 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.

CEER 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 collecting 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 position and as such, it is a very low cost, efficient collector that can be used to produce solar steam at a very low installed cost.

Presently, there is a project to produce steam for the Bacardi Rum Distillery in Toa Baja (Palo Seco). This project is co-sponsored by Bacardi. The results of this project can be extrapolated to 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. It could produce a 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 include economical feasibility and optimization studies and plans to provide steam in the order of 33 million pounds per day to an ethanol plant (producing 11.1% of the gasoline requirements by the year 1986). We aim to develop the R&D Program to make such a project operational by the year 1986. We intend to extend the technology for general industrial uses by the year 1988 to the use-level of 5 percent of industry oil requirement for the year 1988 and 10% by 1990-1995.

R&D Funds Requirements: The R&D requirements are figured as follows:

D. 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 is.

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

1987: 1.85
1988: 2.0
1990: 2.16
1991: 2.33

Environmental Research Scenarios for Solar Steam: The same environmental considerations given to the photovoltaic states and cogeneration concepts applies to the solar steam concept.

Year	Photovoltaics	Biomass	Ethanol	Solar Steam	Total
1982	3.41	3.2	1.97	0.81	9.39
1983	3.09	1.26	1.26	7.3	12.91
1984	4.09	2.7	2.06	10.07	18.92
1985	5.24	5.08	2.21	15.38	27.91
1986	5.06	2.95	N/A	9.62	17.63
1987	7.4	1.85	N/A	9.7	18.95
1988	2.00	4.00	2.00	2.00	10.00
1989	2.16	N/A	2.16	2.16	6.48
1990	2.35	2.33	N/A	3.5	8.18
Total	35.2	23.67	9.66	69.22	137.75

(1) Assumes Federal Government Participation in a ratio of 4.88 to 1.0, where the Puerto Rico.
(2) Assumes equal participation by the Federal Government (DOE).
(3) Latest estimate revised by Dr. A. G. Alexander is six million dollars.

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

[Table not included in the text]

Note: This is best I could do with the provided text as it wasn't clear in many parts and there were numbers without context.

— V6200 63.3 175.61 y2.6 e016 $155,829, (1) Statistical correlations between population and GXP and between GXP and Electrical Energy Generation. Correlation 998. See appendix A. (2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.6% actual. More accurate predictions to be included in Clean Energy Studies. (3) Industrial needs projected at 5% per year growth. More accurate predictions to be included in CEER Energy Studies. (4) Fuel oil prices escalation indicated approximately 1960-85: 14.32/year; 1985-90: 11% year; 1990-95: 6.8%/year and 1995-2000; 6.2%/year. -29-

Schedule 24: Schedule of Proposed Scenarios. Data to be executed and forecasted. Includes info for 1987 to 2000.

(1) An increase of 9-500m base load units will be required in the period considered. Additional power sites need to be added. (2) Estimated 80 lbs per ton of (5% moisture) bagasse.

Potential Energy and Cost Reductions with Example Scenarios. Includes TEU, savings extensions, and other scenarios.

Table 5: Possible Other Revenues.

The text appears to be a mix of unrelated sentences, symbols, and numbers, making it difficult to decipher and correct. However, it seems to pertain to energy and environmental problems in Puerto Rico, with references to long range forecasts of energy needs. The text may need to be provided in a more coherent and comprehensive manner for proper correction.

In a qualitative sense, a 40-year period, up to the year 2000, is believed to be long enough to provide such an extrapolation and at the same time provide energy planners with an overview of the next four decades for the adequate focusing of energy alternatives. GEER's interest is mainly in the energy or fuel alternative scenarios 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 to avoid complicating 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. The aforementioned factors were statistically analyzed in making the prediction. Once the mathematical relationships were established, judgment from past experience and insight into new technologies and changing habits were considered to select the most appropriate relationship. The energy prediction was based simply on a correlation between the total GNP at constant prices and electrical energy. The GNP was predicted from the product of population predictions, times the GNP/capita prediction at constant prices. Populations have already been predicted by the Planning Board up to the year 2000, and GNP up to the year 1983. Therefore, our predictions will be 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 the prediction to a certain degree.

Population growth. Meléndez (2) indicates that the growth rate of the economy of a nation responds better to a moderate increase in the population, than to a rapid growth rate as is the present case concerning Puerto Rico, where the population has doubled in less than 35 years. This information was presented at the Conference on Economy and Population, Dr. James A. Santiago Melendez, as part of the Series of Conferences and Forums: No. 4, Department of Economics, University of Puerto Rico, Rio Piedras, Puerto Rico.

On the other hand, a slow population growth rate, such as a doubling of population every 200 years, can create problems as the population matures in age and there aren't enough youth to replace those leaving the labor force. This has been experienced in certain areas of Japan. However, the concept of optimal population growth is difficult to determine because of the many factors involved.

The Planning Board has predicted 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 been made. The population of Puerto Rico in 1960 was approximately one half of that predicted by the Planning Board for the year 2000, i.e., the predictions indicated 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 predictions up to the year 2000 as input data to the regression analysis in which the total number of input points is 22, gives the following equation: $y_p = 2166.9 + 65.05 x$ where y_p = population in thousands, x = year referred to the 1960 base year (i.e., year less 1960). The coefficient of determination of the above equation is not given.

0.98, indicating a significant correlation of 99%. 'The predicted population, calculated in this manner for the year 2020, will be 6,070,110. The approximate doubling time of the present estimated population of 3,338,000, using the above linear relationship, is 51.3 years. This is within the range satisfactory for adequate economic growth as pointed out by the leader. An exponential regression of population was also attempted. The exponential relation gave the same degree of correlation and coefficient of determination as the linear relationship, but the doubling time of the present population was 35 years. Since this should not be the policy of the government as previously indicated, it was discarded. The exponential relationship was population equals to 2308.66, times "e" elevated to the exponent 0.024, x having the same meaning as before. The predicted population for the year 2020 with this exponential relation was 7,300,580. This was dismissed. The more appropriate linear correlation indicates a population in the year 2020 of 6,070,110.

The predicted population data to be used in the study are:

TABLE 1 - POPULATION BY LINEAR REGRESSION MODEL

YEAR	POPULATION (millions)
1979	3.47
1980	3.59
1981	3.65
1982	3.70
1983	3.78
1985	3.92
1990	4.26
1995	4.52
2000	4.67
2005	5.09
2010	5.42
2015	5.75
2020	6.07

It will be assumed in this study that the overall economic welfare of the country will be maintained and improved. The GNP per capita in constant dollars is a measure of this index. Therefore, if the total economic welfare of the country is to be improved, the GNP per capita in constant dollars should reflect a small or moderate yearly increase. The total GNP at constant dollars compared to the population growth rate should then reflect a yearly increase of at least equal to the rate GNP per capita. The total GNP in current dollars should further reflect any increase due to the inflation price factor.

The Gross National Product (GNP) sums up the economic activities of the country.

In terms of the production of goods and 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 as indicated in Table II below:

TABLE II - ECONOMIC INDEXES
Planning Board Prediction (of GNP) Current Dollars ($ thousands)

	1979	1980	1981	1982	1983
Current $	9835.0	10750	1,693	12,710	13,795
Constant $	4047.4	4298.8	4,549.7	4,814.0	5,090.1

Constant dollars were estimated by assuming a 10 percentage points increment in inflation for the year 1979 and 7 percentage points increment 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.

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These data, together with historical data back to the year 1962, were then analyzed 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 95% coefficient of determination. This fit was: y = 546.87 x 77, where: y = GNP/capita in constant 1954 dollars, x = year - 1960. Predicted values with the above equation indicate yearly improvements in GNP per capita at constant dollars of the order of 0.5 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.

For electrical generation, the total electrical generation was correlated with the total GNP, giving excellent correlations. Results were as follows:

1) Linear Correlation: Coeff. of determination 98%;

Doubling Time: 20 years
2) Power Correlation: Coefficient of determination 98%; Doubling Time: 11 years
3) Log Correlation +: Coefficient of determination 97%; Doubling Time: over 40 years
4) Exp. Correlation: Coefficient of determination 93%; Doubling Time: 5 years.

A statistical test indicated excellent correlations of all 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, if the same level of technology and habits are maintained.

However, it is felt 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. Also, the development of new technologies for producing electrical power from renewable sources (solar) might bring down cost, enhancing an increase in the demand. We, therefore, feel that the power fit represents an adequate description of future electrical generation production. It is given by KWHR gen = (0.001294) (GIP)1+96 x 106 where the unit for GIP is million dollars at 1954 constant.

Table III indicates the correlation data for population, GIP and Electrical Energy. The figures given for electrical energy consumption are comparable to PRWRA forecasts but they tend to be on the low side. Power Technology(3) prediction for the year.

The text should be:

The generation of 2000 is 38,261 x 108 KWtIR, which is comparable to our prediction of 42,910 x 108 KwiR with a difference of 5%. The prediction of electrical energy generation for the year 7020, shown in Figure 1, using the above-selected relationship, is 89,120 million Kur. This is slightly over six times the current electrical energy generation. Therefore, energy planners and researchers must think of energy alternatives for Puerto Rico on a scale as large as six times today's demand by the time when supposedly cost-effective energy alternatives being researched today could become highly competitive economically. Electrical energy is used around the clock, hence, large storage systems for direct solar derived energy must be analyzed in perspective. (By Tong Tange Sales Forecasting Study for the Puerto Rico Water Resources Authority, Kevin A. Clements, and Robert de Mello, Poet Technologies, Inc. Schenectady, N.Y. May 1976.)

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

Fiscal Year	Gnp/capita	Population (Thousands)	GNP ($ millions)	Electric Prod. (106 KW-hr)
1963	694	2,228	1,683.9	2,570.7
1964	736	2,473	1,820.7	2,934.5
1965	768	2,523	1,938.9	3,403.2
1966	861	2,603	2,240.6	4,429.8
1967	892	2,623	2,239.4	5,040.7
1968	927	2,650	2,455.3	5,770.9
1969	1,000	2,685	2,684.0	6,654.5
1970	1,070	2,910	2,901.4	7,339.5
1971	1,120	2,747	3,075.6	8,513.3
1972	1,139	2,823	3,215.9	10,228.0
1973	1,168	2,910	3,450.3	12,778.0
1974	1,168	2,991	3,493.6	13,329.3
1975	1,240	3,076	3,424.7	12,208.9
1976	1,300	3,167	3,487.3	12,349.8
1977	1,316	3,266	3,644.9	13,290.4
1978	1,150	3,338	3,837.5	13,755.9
1979	1,166	3,470	4,087.5	14,611.2
1980	1,217.88	3,530	4,298.84	15,429.16
1981	1,246.52	3,650	4,549.78	16,307.2
1982	1,294.18	3,720	5,214.0	17,519.75
1985	1,310.9	3,920	5,138.7	23,684
1990	1,377.5	4,260	5,868.15	30,734
1995	1,364	4,520	6,492.53	37,483
2000	1,439.4	4,670	6,955.50	42,910
2005	1,537.8	5,090	7,827.40	54,106
2010	1,582.5	5,420	8,577.15	64,748
2015	1,624.0	3,750	9,338.00	76,505
2020	1,662.8	6,070	10,093.20	89,120

*Planning Board

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3. Conferencia sobre Economía y Población, Dr. Jaime A. Santiago Meléndez, Serie de Conferencias y Foros, Departamento de Economía, Universidad de Puerto Rico, Rio Piedras, Puerto Rico.
4. Long Range Sales Forecasting Study for the Puerto Rico Water Resources Authority, Kevin A. Clements and Robert. Mello, Power Technologies, Inc., Schenectady, N.Y., May, 1976.

[Unfortunately, the following text is not clear enough to be accurately interpreted and corrected.]