# PROPOSED SOLUTION FOR ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

UNIVERSITY OF PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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# EXECUTIVE SUMMARY

The Center outlines it's proposed solution for the ominous problems of energy and environment which threaten the well being of the Puerto Rico community. In a national and international context selected alternative energy sources and concomitant environmental problems are elaborated. Necessary funding and 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 U.S. Department of Energy, the Commonwealth Energy Office and the University of Puerto Rico are discussed.

Basic conclusions are (1) Puerto Rico's energy crisis demands an expanded role by CEER in R & D which previous levels of funding and institutional relationships cannot sustain. (2) 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. (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 role is perceived to exist in Puerto Rico. (5) Without adequate support for R & D the energy crisis will reach disastrous proportions.

Recommendations are (1) that the appropriately redefined role in R & D be assigned to the Center and that necessary funds be provided. (2) That CEER remain as a unit within the UPR, but be permitted to retain its innovative practices. (3) Ties with the Office of Energy be strengthened, and (4) Proposed legislation on funding receive the endorsement of the President.

## I. INTRODUCTION AND BACKGROUND

Reorganization in the Federal government since the founding of 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 founding 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 CEER has been quite successful. An examination of progress toward self-sufficiency has revealed important implications for the long term success of the Center. In planning now for the future programs and funding for the Center, considerations must be given not only to assuring continuity and development of the Center, but more importantly to its ability in solving the pressing problems of energy and environment with which Puerto Rico and the whole nation are confronted. The problems in Puerto Rico are great and will require investment of resources which may have not been considered possible five years ago.

The objectives of this document are (1) to present an assessment of the Center's progress toward becoming a self-sustaining and competitive instrument for energy and environmental research in Puerto Rico, (2) to study various institutional frameworks within which the Center could achieve its objectives, (3) to analyze the trajectories which are likely to follow from alternative funding scenarios and (4) to recommend an institutional framework and a strategy for seeking funding which are most appropriate for achieving CEER's short and long run objectives.

## II. THE PRESENT SITUATION AT THE CENTER

The Center counts as its principal resources fourty 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 millions are the best in the Caribbean and the FY 1979 budget amounts to approximately 3.5 millions dollars of which about 2.2 millions represent base funding. The Center has been more successful than expected in securing funding from competitive sources during the first three years of the transition period (having secured $900,000, compared to a predicted $150,000 in FY 1978).

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

When in 1976 it was decided that the Center should begin the transition from a DOE contract facility to integration within the University of Puerto Rico the budget was $2,706,000 of which $1,230,000 was[1] "base" money for training and education. $394,000 was from competitive grants and the remainder in BER.

The decline in base support from DOE may be noted. It is particularly important in the light of the fact that the UPR has not provided substitute funds.

The Center's staff recognizes and understands the difficult resources management problem faced by the University Administration and regrets the circumstances in which the UPR's commitment

(1) See Table I

TABLE 1

PROPOSED TRANSITION FUNDING LEVEL 6/
UNIVERSITY OF PUERTO RICO
ENERGY AND ENVIRONMENT CENTER

| Column (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | Finish Transition |
|---|---|---|---|---|---|---|---|---|
| Funding Source | FY 1976 | FY 1977 | FY 1978 | FY 1979 | FY 1980 1/ | FY 1981 8/ | FY 1982 | FY 1983 |
| Base 2/ | $1,230 | $ 775 | $ 500 | $ 250 | $ 0 | $ 0 | $ 0 | $ 0 |
| Training 2/ | 0 | 100 | 150 | 200 | 250 | 250 | 250 | 250 |
| Development 2/ | 0 | 50 | 250 | 600 | 650 | 500 | 200 | 0 |
| BER | 1,082 | 845 | 900 | 950 | 950 | 1,000 | 1,000 | 1,000 |
| Institutional* | 0 | 100 | 300 | 300 | 300 | 300 | 300 | 300 7/ |
| ERDA Current Programs 3/ | $2,312 | $1,870 | $2,100 | $2,300 | $2,150 | $2,050 | $1,750 | $1,550 |
| New ERDA Programs 4/ | 0 | 0 | 100 | 150 | 250 | 400 | 500 | 600 |
| TOTAL ERDA | $2,312 | $1,870 | $2,200 | $2,450 | $2,400 | $2,450 | $2,250 | $2,150 |
| UPR Medical | 0 | 135 | 270 | 425 | 475 | 450 | 450 | 450 |
| UPR Energy 5/ | 0 | 100 | 100 | 200 | 225 | 250 | 300 | 300 |
| SUB-TOTAL | $2,312 | $2,105 | $2,570 | $3,075 | $3,100 | $3,150 | $3,000 | $2,900 |
| Competitive Funds | 394 | | 900 | | | | | |
| TOTAL | $2,706 | $2,105 | $3,470 | $3,075 | $3,100 | $3,150 | $3,000 | $2,900 |

1/ Facilities should all be fully transferred to UPR during FY 1980.
2/ These three items total the current base budget commitment.
3/ This ERDA Current Program line represents the ERDA "promise" to UPR.
4/ This line is not an ERDA guarantee but an estimate of what UPR may be successful in competing for.
5/ This is UPR contribution to Center activity which may be partly comprised of Work-for-Others.
6/ This level is based on FY 77 dollars.
7/ Amount to be determined based on program and ERDA needs.
8/ DOE-UPR contract ends September 30, 1981.

*Exploratory Research and Program Coordination Funds of support has not been fulfilled in accordance with the provisions of the DOE (ERDA) action memorandum of April 16, 1976.

Faced with the prospect of declining base support and with it the resources to adequately pursue new sources of funding a decline is foreseen in the ability of the Center to respond to Puerto Rico's needs as it has been in the past.

## III. FUTURE PROJECTIONS

### A. Revised Mission

The new mission of CEER is to address energy and environment questions that arise for the industrialized, tropical island of Puerto Rico and to do so in a way which has maximum applicability to other areas.

Puerto Rico needs expert information to guide planners in the orderly development of the island. Orderly development requires the objective assessment of energy alternatives in the context of their environmental and economic costs. CEER is the only institution on the Island with the appropriate orientation, tradition, independence, reputation and expertise to perform this necessary task.

### B. Competitive Funding Prospects

While DOE funding of relevant research is expected to continue it will become a smaller fraction of the total program needs. However, it is unrealistic to expect that the observed rate of increase of competitive funding can be sustained. There is need for research in other areas for which CEER is logically the candidate but the dollars available on the Island are finite and consequently the Center will more and more have to enter into competition 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 CEER staff. This is a contingency for which little provision has been made in CEER structure to date. Using the national average for the rate of rejection of research proposals it may be conservatively estimated that 1.3 man years per year must be spent in grant proposal preparation to yield 1 million dollars of competitive funds.

C. <u>Research to Secure Environmentally Acceptable Energy Alternatives</u>

Vigorous efforts will be required to solve the special energy and environmental problems for Puerto Rico. CEER is already involved in programs having the apppropriate orientation, but much more work will be needed to solve the problem. Several cases may be cited as examples of the relevance and cost effectiveness of CEER's present and planned R & D programs which have relevance for the Commonwealth.

OTEC, photovoltaic, biomass, ethanol and solar steam are under consideration as alternative energy sources for Puerto Rico. More detailed information regarding the R & D scenarios for these may be found in Appendix D.

Considering OTEC as an illustration, plans call for a 40 MW plant generating about 1% of Puerto Rico's energy needs by 1985; a 250 MW Demonstration Plant providing about 4% of energy requirements by 1990; and a possible 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 the Appendix D. The main points to be stressed here are that the technology in question is cost effective but needs to be adapted and expanded for Puerto Rico to make any sort of reasoned approach toward energy independence. CEER is the only agent on the Island capable of and already involved in such work for Puerto Rico and CEER will not without assurances of base funding be able to continue this leadership role.

The summary of the examples scenarios considered, under crash type R & D Program heavily involving CEER, is given in Tables 2 to 6.

Table 2 includes an estimate of the energy requirements in Puerto Rico for the period 1976 through 2000. It is assumed that the present socio-economic structure persists and that no R & D program in search of energy alternatives is functioning. The fuel bill for Puerto Rico during the FY 1979 exceeds one billion dollars and the total bill for the rest of the century is estimated at approximately 156 billion dollars.[2]

(2) Column 6, Table 1.

TABLE 2

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | MILLION BARRELS OF OIL IMPORTS FOR | | | | | |
| YEAR | ELECTRICAL ENERGY (1) | GASOLINE & DIESEL(2) | INDUSTRY & OTHER(3) | TOTAL | ESTIMATED UNIT PRICE (4) $/BBL | TOTAL COST ($ Millions) |
| 1976 | 21.7 | 17.6 | 26.3 | 64.7 | | |
| 1977 | 23.0 | 18.2 | 21.5 | 62.7 | | |
| 1978 | 24.5 | 16.5 | 23.9 | 65.0 | | |
| 1979 | 26.0 | 17.0 | 25.1 | 68.1 | 14.70 | 1001. |
| 1980 | 27.5 | 17.9 | 26.3 | 71.7 | 16.78 | 1203 |
| 1981 | 29.0 | 18.5 | 27.7 | 75.2 | 19.17 | 1442 |
| 1982 | 29.7 | 19.0 | 29.1 | 77.8 | 21.30 | 1704 |
| 1983 | 31.9 | 19.8 | 30.5 | 82.2 | 25.00 | 2055 |
| 1984 | 33.6 | 20.5 | 32.0 | 86.1 | 28.55 | 2458 |
| 1985 | 35.3 | 21.0 | 33.6 | 89.9 | 32.70 | 2939 |
| 1986 | 36.7 | 21.4 | 35.3 | 93.4 | 36.29 | 3390 |
| 1987 | 37.9 | 21.9 | 37.1 | 96.9 | 40.28 | 3903 |
| 1988 | 42.2 | 22.5 | 38.9 | 103.6 | 44.72 | 4633 |
| 1989 | 44.8 | 23.1 | 40.9 | 108.8 | 49.60 | 5396 |
| 1990 | 47.4 | 23.6 | 42.9 | 113.9 | 55.00 | 6266 |
| 1991 | 50.8 | 24.0 | 45.1 | 119.9 | 58.75 | 7044 |
| 1992 | 53.4 | 24.5 | 47.3 | 125.2 | 62.75 | 7856 |
| 1993 | 56.0 | 25.1 | 49.7 | 130.8 | 67.00 | 9295 |
| 1994 | 59.1 | 25.7 | 52.2 | 137.0 | 71.50 | 9796 |
| 1995 | 62.0 | 26.0 | 54.8 | 142.8 | 76.50 | 10924 |
| 1996 | 65.0 | 26.4 | 57.5 | 148.9 | 81.12 | 12078 |
| 1997 | 68.1 | 26.7 | 60.4 | 155.2 | 86.00 | 13347 |
| 1998 | 71.5 | 27.4 | 63.4 | 162.3 | 91.15 | 14793 |
| 1999 | 74.1 | 27.9 | 66.6 | 168.6 | 96.62 | 16290 |
| 2000 | 77.6 | 28.1 | 69.9 | 175.6 | 102.6 | 18016 |
| TOTAL | | | | | | $155,829 |

(1) Statistical Correlations between population and GNP and between GNP and Electrical Energy Generation. Correlation 99%. See Appendix E

(2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.6% 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 proces escalation indicated is approximately 1980-85: 14.3%/year; 1985-90: 11% year; 1990-95: 6.8%/year and 1995-2000: 6% 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 CEER 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 crash program by the indicated scenarios.

Table 4 illustrates the potential contribution of the proposed energy alternatives scenarios to the total fuel oil consumption of Puerto Rico. A reduction of nearly 52 billion 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 R & D crash programs requiring inter-agency coordination and cooperation.

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

TABLE 3A

SCHEDULE OF PROPOSED SCENARIOS PROGRAM OBJECTIVES

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| YEAR | OTEC | ELECTRIC (1) PHOTOVOLTAICS ELEC.MW | STEAM $10^6$BOil | BIOMASS | ETHANOL %ofgas.req.) | DIRECT SOLAR STEAM (OIL SAV.) MILLION BBL OIL ETHANOL PLT. | IND. STEAM |
| 1979-84 | | | | | | | |
| 1985 | 1-40MW | | | | | | |
| 1986 | | | | | 11% | 2.0 | |
| 1987 | | | | 450MW | | 2.0 | |
| 1988 | | | | | 22% | 4.0 | 2.0 |
| 1989 | | | | 450MW | | 4.0 | 2.0 |
| 1990 | 1-250MW | | | | 33% | 6.0 | 4.0 |
| 1991 | | | | | | 6.0 | 4.0 |
| 1992 | | | | | | 6.0 | 4.0 |
| 1993 | | 250MW | 3.7 | | | 6.0 | 4.0 |
| 1994 | | | | | | 6.0 | 4.0 |
| 1995 | 1-500MW | | | | | 6.0 | 6.0 |
| 1996 | | 250MW | 3.7 | | | 6.0 | 6.0 |
| 1997 | 1-500MW | | | | | 6.0 | 6.0 |
| 1998 | 1-500MW | | | | | 6.0 | 6.0 |
| 1999 | 1-500MW | | | | | 6.0 | 6.0 |
| 2000 | | | | | | 6.0 | 6.0 |

(1) At least 9-500MW base load units will be required in the period considered. Additional fossil fueled units needs to be added.

TABLE 3B

POSSIBLE MILLIONS BARRELS OIL SAVED WITH PROPOSED SCENARIOS

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| YEAR | OTEC | PHOTOVOLTAICS ELECTR. | STEAM | BIOMASS | ETHANOL Gasohol | Electric(2) | STEAM | TOTALS |
| 1985 | .53 | | | | | | | 0.53 |
| 1986 | .53 | | | | 1.87 | 1.24 | 2.0 | 5.64 |
| 1987 | .53 | | | 5.3 | 1.87 | 1.24 | 2.0 | 10.94 |
| 1988 | .53 | | | 5.3 | 3.74 | 1.25 | 6.0 | 18.07 |
| 1989 | .53 | | | 10.6 | 3.74 | 1.25 | 6.0 | 23.40 |
| 1990 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1991 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1992 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1993 | 3.86 | 3.53 | 3.7 | 10.6 | 5.61 | 3.7 | 10.0 | 40.50 |
| 1994 | 3.86 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 10.0 | 44.17 |
| 1995 | 10.53 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 12.0 | 52.84 |
| 1996 | 10.53 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 60.01 |
| 1997 | 17.20 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 66.38 |
| 1998 | 23.84 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 73.35 |
| 1999 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |
| 2000 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |

(2) Estimated 80 kwhr per ton of (51% moisture) baggase.

TABLE 4

POTENTIAL, "ENERGY AND COST REDUCTIONS"
WITH EXAMPLE SCENARIOS

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| | CONSUMPTION MILLION BARRELS OIL | | REDUCTION $10^6$ BBLS | MILLION DOLLARS | FRACTION (%) OF SCENARIOS |
| YEAR | NO SCENARIOS | WITH EXAMPLE SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS OF TOTAL-NON SCENARIOS |
| 1985 | 89.9 | 89.37 | 0.53 | 17.33 | 0.5% |
| 1986 | 93.4 | 87.76 | 5.64 | 204.67 | 6% |
| 1987 | 96.9 | 85.96 | 10.94 | 440 | 11% |
| 1988 | 103.6 | 85.53 | 18.07 | 808 | 17% |
| 1989 | 108.8 | 85.40 | 23.40 | 1,160 | 21% |
| 1990 | 113.9 | 80.13 | 33.77 | 1,857 | 30% |
| 1991 | 119.9 | 86.13 | 33.77 | 1,984 | 28% |
| 1992 | 125.2 | 91.43 | 33.77 | 2,119 | 27% |
| 1993 | 130.8 | 90.30 | 40.50 | 2,714 | 29% |
| 1994 | 137.0 | 92.83 | 44.17 | 3,158 | 32% |
| 1995 | 142.8 | 89.96 | 52.84 | 4,042 | 37% |
| 1996 | 148.9 | 88.89 | 60.01 | 4,868 | 40% |
| 1997 | 155.2 | 88.82 | 66.38 | 5,709 | 43% |
| 1998 | 162.3 | 88.95 | 73.35 | 6,886 | 47% |
| 1999 | 168.6 | 88.58 | 80.02 | 7,732 | 47% |
| 2000 | 175.6 | 95.58 | 80.02 | 8,210 | 46% |
| TOTALS | 2072.8 | 1415.62 | 657.18 | 51,909.0 | 36% |
| COST $\$10^6$ | :145,966 | | | | |

TABLE 5

POSSIBLE CEER REVENUES FROM FUELS TAX R&D LAW

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| YEAR | MILLION BARRELS | 1.5c/$10^6$ BTU TAX | | 2c/$10^6$ BTU TAX | | 2.5c/$10^6$ BTU TAX | |
| | CONSUMPTION with SCENARIOS | $\$10^6$ | % | $\$10^6$ | % | $\$10^6$ | % |
| 1980 | 71.70 | 6.45 | 0.53 | | | | |
| 1981 | 75.20 | 6.77 | 0.47 | | | | |
| 1982 | 77.80 | | | 9.34 | 0.55 | | |
| 1983 | 82.20 | | | 4.86 | 0.48 | | |
| 1984 | 86.10 | | | | | 12.92 | .53 |
| 1985 | 89.37 | | | | | 13.41 | .46 |
| 1986 | 87.76 | | | | | 13.16 | .41 |
| 1987 | 85.96 | | | | | 12.89 | .37 |
| 1988 | 85.53 | | | | | 12.83 | .33 |
| 1989 | 85.40 | | | | | 12.81 | .30 |
| 1990 | 80.13 | | | | | 12.02 | .27 |
| 1991 | 86.13 | | | | | 12.92 | .26 |
| 1992 | 91.43 | | | | | 13.71 | .24 |
| 1993 | 90.30 | | | | | 13.55 | .22 |
| 1994 | 92.83 | | | | | 13.92 | .21 |
| 1995 | 89.96 | | | | | 13.49 | .20 |
| 1996 | 88.89 | | | | | 13.32 | .18 |
| 1997 | 88.82 | | | | | 13.32 | .17 |
| 1998 | 88.95 | | | | | 13.34 | .16 |
| 1999 | 88.58 | | | | | 13.29 | .16 |
| 2000 | 95.58 | | | | | 14.34 | .15 |

Table 6 illustrates the total CEER funds 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 is the minimum projected funding requirements for CEER. If the proposed example scenarios or any other similar type program is not undertaken, CEER still needs to be funded to the level shown in the indicated column. This is discussed more fully in the section below.

An adequate attempt to solve the energy problems of Puerto Rico will require that during the period 1980 to 1990 a total of approximately $199 million (3) be made available

This represents an average investment in R & D for energy and environment in the vicinity of $18 million annually.

## IV. ALTERNATIVE INSTITUTIONAL FRAMEWORKS

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

### A. Continue within the existing organizational structure of UPR and extend the present relationship with DOE.

Pro 1- DOE is well aware of the capabilities of CEER and is likely to approve some continuing relationship.

Pro 2- The UPR is likely to continue to look favorably upon CEER activities and give it wholehearted support.

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(3) Column 14, Table 6

TABLE 6

TOTAL CEER FUNDS REQUIREMENTS FOR
OTEC, PHOTOVOLTAICS, BIOMASS, ETHANOL AND SOLAR STEAM R&D PROGRAMS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OTEC | | PHOTOVOLTAICS | | BIOMASS | | ETHANOL | | SOLAR STEAM | | | | | | |
| YEAR | OTEC | ADV. OTEC | PHOTOV. PROJECT | ADV. CONCEP. | DIRECT FIRING | ADV. CONCEP. | PROJECT | ADV. CONCEP. | PROJECT | ADV. CONCEP. | TOTALS SCENARIOS ( cols.) | BASE FUNDING REQ. (4) | TOTAL CEER FUNDING WITH SCENARIOS Col. 12 + Col. 13 | TAX LAW P. R. | EXTERNAL FUNDING (EXC. OF DOE PROJECTS Col. 14-Col. 15 |
| 1980 | 3.11 | | .54 | | 2.16 | | .54 | | .10 | | 6.45 | 3.0 (1) | 9.45 | 6.45 | 3.0 (1) |
| 1981 | 3.97 | | .81 | | .59 | | 1.17 | | .23 | | 6.77 | 2.5 (2) | 9.27 | 6.77 | 2.5 (2) |
| 1982 | 3.93 | | 1.26 | | .50 | | 1.26 | | .38 | | 7.33 | 2.8 | 10.13 | 9.34 | 0.79 |
| 1983 | 4.09 | | 2.72 | | .54 | | 2.04 | | .68 | | 10.07 | 3.0 | 13.07 | 9.86 | 3.21 |
| 1984 | 5.24 | | 5.88 | | .59 | | 2.21 | | 1.47 | | 15.39 | 3.2 | 18.59 | 12.92 | 5.67 |
| 1985 | 5.86 | | 7.95 | | .64 | | 1.59 | .4 | 3.18 | | 19.62 | 3.5 | 23.12 | 13.41 | 9.71 |
| 1986 | | 1.71 | 8.55 | | | .80 | 1.28 | .86 | 8.55 | .8 | 22.55 | 3.8 | 26.35 | 13.16 | 13.19 |
| 1987 | | 1.85 | 7.40 | 1.85 | | 1.85 | .93 | 1.85 | 3.70 | 1.85 | 21.28 | 4.1 | 25.38 | 12.81 | 12.57 |
| 1988 | | 2.00 | 4.00 | 2.00 | | 2.00 | .50 | 2.00 | 4.00 | 2.00 | 18.50 | 4.4 | 22.90 | 12.02 | 10.88 |
| 1989 | | 2.16 | 1.62 | 2.16 | | 2.16 | .54 | 3.24 | 2.16 | 2.16 | 16.20 | 4.8 | 21.00 | 12.92 | 8.08 |
| 1990 | | 2.33 | | 2.33 | | 2.33 | .58 | 3.50 | 1.17 | 2.33 | 14.57 | 5.1 | 19.67 | 13.71 | 5.96 |
| Tot. | 26.2 | 10.05 | 40.73 | 8.34 | 5.02 (3) | 9.14 | 12.64 | 11.85 | 25.62 | 9.14 | 158.73 | 40.2 | 198.63 | 123.37 | 75.56 |

(1) Include Decontamination Program of Reactor at Mayaguez.
(2) Present CEER-DOE contract expires in FY 1981
(3) Latest estimate revised by Dr. A. G. Alexander is six million dollars.
(4) Projections after 1980 at 8% per year escalation.

Pro 3- Continuity will not require any adjustment to the new perspective which might be required if a new sponsor or organizational location results.

Con. 1- Levels of funding will not approach the amounts required in an adequate program as outlined above.

Con. 2- Increases in funding from UPR are not likely to be forthcoming given the percentage commitment which has been realized in the past.

Con. 3- The alternative will not provide the dynamic organization and response which Puerto Rico's energy and energy research problems demand.

B. Integration with the Puerto Rico Office of Energy to form a State level counterpart to U.S./DOE.

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

Pro 2- More efficient utilization of resources might be achieved.

Pro 3- Possible sponsors or funding might be attracted by the combined efforts.

Con 1- The executive branch of government is not supportive of research activities. "Operational" and "Service" considerations usually outweight research needs.

Con 2- Full integration within the public service might rigidify the organization and might lessen the responsiveness and flexibility which have characterized it until now.

Con 3- A new Department of Energy would suffer the normal growth and development problems in a new bureaucratic structure. How long it would take to get beyond its own problems of organization to those of energy and environment is an open question.

C. Establishing an Independent Private Entity

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

D. Modifying Present Arrangements with UPR

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

Objections to this arrangement can be expected, resistance might be overcome by paying dividends on stocks or interest on bonds to the University and by a contractural agreement to provide limited free research assistance and facilities. The advantage to the University would be an immediate reduction in operating costs, and if CEER were successful, there would be the potential of a good income from both Government and private sources.

## V. 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 exists for negotiating a new contract with DOE but it is the general consensus of the staff that the level of funding will not be close to that desired to 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

5% of its gross revenues to the State General Fund. However, recent ammendments has committed fully this contribution in relation with the fuel adjustment clause subsidy given to consumers with less than 400 kwhrs monthly. The alternative was discarded.

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

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

## VI. CONCLUSIONS

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

2. 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.

3. 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.

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.

VIII. RECOMMENDATIONS:

1. It is recommended (1) that the appropriately redefined role in & D be assigned to the Center and that necessary funds be provided, (2) that CEER remain as a unit within the UPR system, but be permitted to retain its innovative practices, (3) that tieswith the Office of Energy be strengthened, (4) that proposed legislation on funding receive the endorsement of the President.

# ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

## APPENDIX A

## MISCELLANEOUS FUNDING SOURCES

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX A

MISCELLANEOUS FUNDING SOURCES

I. PATENTS

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

II. PUBLICATIONS AND DATA SERVICES

As a further revenue generator it is recommended that the possibility of establishing a Publications and Information Division be explored. Offerings for public sale would include items in Education, Research and Service in the fields of Energy and Environment. The publications would be available in Spanish and English with selected items in Portuguese and French.

In addition to publications a service could be offered in providing basic data in Energy and Environment to interested parties. In the past data related to solar applications has been requested by domestic and foreign corporations holding contracts with private industry or government agencies. Direct and difuse radiation data collected in our measuring stations has been requested and provided without charge. The companies using the data charge their clients for this service. It would seem reasonable that a policy for recovering costs to the Center could be implemented. In similar fashion it would be possible to recover the cost of publications such as those pertaining to solar applications for domestic solar heaters from which there is an obvious benefit to the consumer.

## III. INDUSTRIAL LIAISON PROGRAM

As part of its design for continuity and development CEER has established an Industrial Liaison Office. The function of this office is to provide essential services to industry in supplying information to prepare reports on the state-of-the-art in pertinent fields, organizing conferences and symposia, and various other services. Interaction between industry and the University,long discussed but short on actual exchange of meaning between the two promises soon to be a reality.

An analysis of counterpart activities at leading Universities on the mainland suggests that the Massachusetts Institute of Technology (MIT) Model is the most appropriate. Discussions have already taken place with MIT and CEER personnel participating. No relevant obstacles are anticipated in putting the program in operation. Revenue generated by the program will lessen the financial burden of the Center.

# ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

## APPENDIX B

## PROPOSED LEGISLATION

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX B

A BILL FOR APPROPRIATING FUNDS FOR THE

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

STATEMENT OF MOTIVES

The Center for Energy and Environment Research of the University of Puerto Rico is an institution dedicated to the study and development of new energy resources such as the sun, wind, and sea while also exploring the potentials inherent in recycling, conversion, or elimination of the waste products and pollutants of modern society. Among its current projects are the development of solar photovoltaics, ocean thermal energy conversion, use of sugar cane hybrids as biomass fuel, bilharzia control, effects of industrial developments and population growth on land masses, etc.

The Center's principal objectives:

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

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

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

The Center for Energy and Environment Research of the University of Puerto Rico, evolved from the Puerto Rico Nuclear Center, established by the U.S. Atomic Energy Commission in 1957. The Nuclear Center was operated by the University of Puerto Rico for the Commission until the agency was superseded by the U.S. Energy Research and Development Administration (ERDA) in 1975. The Nuclear Center trained more than 2,000 students in nuclear sciences, engineering and medicine. Now the Department of Energy is funding CEER through a contract with the University of Puerto Rico. This evolvement 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 or conservation.

The current energy crisis which is caused by a world energy shortage is expected to get worse through the remainder of this century. Puerto Rico, with its total dependence for energy on imported fossil fuel, is particularly vulnerable to dislocations 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 doing 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.

In September 30, 1981 the contract expires and thereafter DOE will not cover the operational costs of the CEER and although the funds obtained from grants on a competitive basis will continue they will not be enough to cover all the expenses. It is therefore, necessary that the Legislature appropriate the necessary funds to cover the 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 said purpose,

Be it enacted by the Legislature of Puerto Rico

1- It is hereby found and declared that the purposes of the Center for Energy and Environment Research (CEER) of the University of Puerto Rico are for the development of environmentally acceptable energy alternatives through research on new fuels to substitute for those made from petroleum and research to understand and protect the ecology and natural resources of the Island and that said 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 to perform research and development is already established, due to which it is necessary that the Legislature appropriate the required funds to continue the same.

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

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 or its equivalent for the first two fiscal year (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 therein 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 take effect ninety (90) days after its approval.

# ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

## APPENDIX C

## INNOVATIONAL ORGANIZATIONAL STRUCTURE WITHIN UNIVERSITY OF PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX C

THE POSSIBILITIES OF ESTABLISHING AN INDEPENDENT R&D CENTER INTEGRATED WITH THE UNIVERSITY SYSTEM

Given both the history of CEER and its current mode of operations, it is clear that it could, and does in fact, operate as a relatively autonomous arm of the University of Puerto Rico. While subject to general university policies and reporting directly to the Office of the President, its routine activities and its relationships with other institutions are determined by the Director and implemented by the in-house staff.

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

## GENERAL CONSIDERATIONS

### Implementation Procedures

1- Preparation of preliminary proposal and time schedule by CEER

2- Establishment of URP/CEER Liaison work committee to draft necessary legal / University and administration steps.

3- Stepwise authorization by President, University Board, CHE as required.

4- Establishment of non profit corporate legal structure.

5- Organizing of Board of Directors

6- Establishment of CEER administration

7- Arrange transfer or long term lease of CEER facilities for UPR to CEER for UPR equity.

8- Establish CEER-UPR financial relationship.

9- Establish CEER-UPR scientific relationship.

### Implementation Requisites

1- CEER base funding sufficient for 5-10 year minimum operating level.

2- CEER competitive funding growing at established rate.

3- UPR willing to develop this relationship.

4- All legal and university regulations allow implementation or can be modified to fit the situation.

# ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

## SUMMARY

## APPENDIX D

## EXAMPLES OF ALTERNATIVE SCENARIOS IN ENERGY AND ENVIRONMENT

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

7 April 1979

# THE ENERGY PROBLEM IN PUERTO RICO

Various efforts are being undertaken by a variety of organizations in the Puerto Rico Government in the pursuing of solutions to the energy and environment 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. Probably, 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 Puertorrican livelihood, economics, health and every sector of the very life and blood of the present civilization as we know in the western world. It is, therefore, felt that an outlook with an agressive energy program with definite goals and objectives should be developed and pursued to bring forth solutions in the shortest time possible but with known and calculated acceptable risks.

CEER studies on the economy of Puerto Rico and the dynamics of population growth predicts 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 E "Long Range Forecast of Energy Needs in Puerto Rico" describes the Model Used for the 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 keep just approximately the same level of economic welfare. This statement, under the present serious prediction of increasing fossil fuel costs and scarcity of fuel oils is rather alarming. An agressive 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:

1- OTEC
2- Photovoltaics
3- Biomass
4- Ethanol (Motor Fuels)
5- 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 evaluated economically 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 2 to 6. The following traces out the salient points of the overall proposal. Appropriate detail is 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 in 155.829 billion dollars.

Table 3A presents the mentioned example Program of energy alternative objectives under a very tight schedule, only achievable by a concentrated and coordinated effort between the various government energy planning related organizations and in which CEER is the main R & D researcher.

Table 3B indicates the barrels of oil saved by the proposed crash program example scenarios.

Table 4 illustrates the effect of the example energy alternatives scenarios proposed in the total fuel oil consumption of Puerto Rico. A reduction of nearly 52,000 million dollars equivalent to

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | MILLION BARRELS OF OIL IMPORTS FOR | | | | | |
| YEAR | ELECTRICAL ENERGY (1) | GASOLINE & DIESEL(2) | INDUSTRY & OTHER(3) | TOTAL | ESTIMATED UNIT PRICE (4) $/BBL | TOTAL COST ($ Millions) |
| 1976 | 21.7 | 17.6 | 26.3 | 64.7 | | |
| 1977 | 23.0 | 18.2 | 21.5 | 62.7 | | |
| 1978 | 24.5 | 16.5 | 23.9 | 65.0 | | |
| 1979 | 26.0 | 17.0 | 25.1 | 68.1 | 14.70 | 1001. |
| 1980 | 27.5 | 17.9 | 26.3 | 71.7 | 16.78 | 1203 |
| 1981 | 29.0 | 18.5 | 27.7 | 75.2 | 19.17 | 1442 |
| 1982 | 29.7 | 19.0 | 29.1 | 77.8 | 21.30 | 1704 |
| 1983 | 31.9 | 19.8 | 30.5 | 82.2 | 25.00 | 2055 |
| 1984 | 33.6 | 20.5 | 32.0 | 86.1 | 28.55 | 2458 |
| 1985 | 35.3 | 21.0 | 33.6 | 89.9 | 32.70 | 2939 |
| 1986 | 36.7 | 21.4 | 35.3 | 93.4 | 36.29 | 3390 |
| 1987 | 37.9 | 21.9 | 37.1 | 96.9 | 40.28 | 3903 |
| 1988 | 42.2 | 22.5 | 38.9 | 103.6 | 44.72 | 4633 |
| 1989 | 44.8 | 23.1 | 40.9 | 108.8 | 49.60 | 5396 |
| 1990 | 47.4 | 23.6 | 42.9 | 113.9 | 55.00 | 6266 |
| 1991 | 50.8 | 24.0 | 45.1 | 119.9 | 58.75 | 7044 |
| 1992 | 53.4 | 24.5 | 47.3 | 125.2 | 62.75 | 7856 |
| 1993 | 56.0 | 25.1 | 49.7 | 130.8 | 67.00 | 9295 |
| 1994 | 59.1 | 25.7 | 52.2 | 137.0 | 71.50 | 9796 |
| 1995 | 62.0 | 26.0 | 54.8 | 142.8 | 76.50 | 10924 |
| 1996 | 65.0 | 26.4 | 57.5 | 148.9 | 81.12 | 12078 |
| 1997 | 68.1 | 26.7 | 60.4 | 155.2 | 86.00 | 13347 |
| 1998 | 71.5 | 27.4 | 63.4 | 162.3 | 91.15 | 14793 |
| 1999 | 74.1 | 27.9 | 66.6 | 168.6 | 96.62 | 16290 |
| 2000 | 77.6 | 28.1 | 69.9 | 175.6 | 102.6 | 18016 |
| TOTAL | | | | | | $155,829 |

(1) Statistical Correlations between population and GNP and between GNP and Electrical Energy Generation. Correlation 99%. See Appendix E

(2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.6% 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 proces escalation indicated is approximately 1980-85: 14.3%/year; 1985-90: 11% year; 1990-95: 6.8%/year and 1995-2000: 6% year.

TABLE 3A

SCHEDULE OF PROPOSED SCENARIOS PROGRAM OBJECTIVES

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | | ELECTRIC (1) | | | | | |
| YEAR | OTEC | PHOTOVOLTAICS ELEC. MW | PHOTOVOLTAICS STEAM $10^6$BOi | BIOMASS | ETHANOL %ofgas.req.) | DIRECT SOLAR STEAM (OIL SAV. MILLION BBL OIL ETHANOL PLT. | IND. STEAM |
| 1979-84 | | | | | | | |
| 1985 | 1-40MW | | | | | | |
| 1986 | | | | | 11% | 2.0 | |
| 1987 | | | | 450MW | | 2.0 | |
| 1988 | | | | | 22% | 4.0 | 2.0 |
| 1989 | | | | 450MW | | 4.0 | 2.0 |
| 1990 | 1-250MW | | | | 33% | 6.0 | 4.0 |
| 1991 | | | | | | 6.0 | 4.0 |
| 1992 | | | | | | 6.0 | 4.0 |
| 1993 | | 250MW | 3.7 | | | 6.0 | 4.0 |
| 1994 | | | | | | 6.0 | 4.0 |
| 1995 | 1-500MW | | | | | 6.0 | 6.0 |
| 1996 | | 250MW | 3.7 | | | 6.0 | 6.0 |
| 1997 | 1-500MW | | | | | 6.0 | 6.0 |
| 1998 | 1-500MW | | | | | 6.0 | 6.0 |
| 1999 | 1-500MW | | | | | 6.0 | 6.0 |
| 2000 | | | | | | 6.0 | 6.0 |

(1) At least 9-500MW base load units will be required in the period considered. Additional fossil fueled units needs to be added.

TABLE 3B

POSSIBLE MILLIONS BARRELS OIL SAVED WITH PROPOSED SCENARIOS

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| YEAR | OTEC | PHOTOVOLTAICS | | BIOMASS | ETHANOL | | STEAM | TOTALS |
| | | ELECTR. | STEAM | | Gasohol | Electric (2) | | |
| 1985 | .53 | | | | | | | 0.53 |
| 1986 | .53 | | | | 1.87 | 1.24 | 2.0 | 5.64 |
| 1987 | .53 | | | 5.3 | 1.87 | 1.24 | 2.0 | 10.94 |
| 1988 | .53 | | | 5.3 | 3.74 | 1.25 | 6.0 | 18.07 |
| 1989 | .53 | | | 10.6 | 3.74 | 1.25 | 6.0 | 23.40 |
| 1990 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1991 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1992 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1993 | 3.86 | 3.53 | 3.7 | 10.6 | 5.61 | 3.7 | 10.0 | 40.50 |
| 1994 | 3.86 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 10.0 | 44.17 |
| 1995 | 10.53 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 12.0 | 52.84 |
| 1996 | 10.53 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 60.01 |
| 1997 | 17.20 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 66.38 |
| 1998 | 23.84 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 73.35 |
| 1999 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |
| 2000 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |

(2) Estimated 80 kwhr per ton of (51% moisture) baggase.

TABLE 4

POTENTIAL, "ENERGY AND COST REDUCTIONS" WITH EXAMPLE SCENARIOS

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| YEAR | CONSUMPTION MILLION BARRELS OIL | | REDUCTION $10^6$ BBLS | MILLION DOLLARS | FRACTION (%) OF SCENARIOS |
| | NO SCENARIOS | WITH EXAMPLE SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS OF TOTAL-NON SCENARIOS |
| 1985 | 89.9 | 89.37 | 0.53 | 17.33 | 0.5% |
| 1986 | 93.4 | 87.76 | 5.64 | 204.67 | 6% |
| 1987 | 96.9 | 85.96 | 10.94 | 440 | 11% |
| 1988 | 103.6 | 85.53 | 18.07 | 808 | 17% |
| 1989 | 108.8 | 85.40 | 23.40 | 1,160 | 21% |
| 1990 | 113.9 | 80.13 | 33.77 | 1,857 | 30% |
| 1991 | 119.9 | 86.13 | 33.77 | 1,984 | 28% |
| 1992 | 125.2 | 91.43 | 33.77 | 2,119 | 27% |
| 1993 | 130.8 | 90.30 | 40.50 | 2,714 | 29% |
| 1994 | 137.0 | 92.83 | 44.17 | 3,158 | 32% |
| 1995 | 142.8 | 89.96 | 52.84 | 4,042 | 37% |
| 1996 | 148.9 | 88.89 | 60.01 | 4,868 | 40% |
| 1997 | 155.2 | 88.82 | 66.38 | 5,709 | 43% |
| 1998 | 162.3 | 88.95 | 73.35 | 6,886 | 47% |
| 1999 | 168.6 | 88.58 | 80.02 | 7,732 | 47% |
| 2000 | 175.6 | 95.58 | 80.02 | 8,210 | 46% |
| TOTALS | 2072.8 | 1415.62 | 657.18 | 51,909.0 | 36% |
| COST $\$10^6$ | :145,966 | | | | |

36% of the total dollar expenditures up to the year 2000 is 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 and D program. A fuel tax for energy and environmental research and development is proposed on all non-renewable fuels consumption in Puerto Rico. The tax proposed is based on BTU consumption and it fluctuates between 1.5c to 2.5c per million BTU. A gallon of gasoline contains some 140,000 BTU, therefore, this would hardly add 0.2 - 0.35 cents to a gallon of gasoline.

Table 6 illustrates the total CEER funds requirements for the example scenarios. The last two columns of Table 6 indicate the suggested source of funding.

TABLE 5

POSSIBLE CEER REVENUES FROM FUELS TAX R&D LAW

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| YEAR | MILLION BARRELS | 1.5c/$10^6$ BTU TAX | | 2c/$10^6$ BTU TAX | | 2.5c/$10^6$ BTU TAX | |
| | CONSUMPTION with SCENARIOS | $\$10^6$ | % | $\$10^6$ | % | $\$10^6$ | % |
| 1980 | 71.70 | 6.45 | 0.53 | | | | |
| 1981 | 75.20 | 6.77 | 0.47 | | | | |
| 1982 | 77.80 | | | 9.34 | 0.55 | | |
| 1983 | 82.20 | | | 4.86 | 0.48 | | |
| 1984 | 86.10 | | | | | 12.92 | .53 |
| 1985 | 89.37 | | | | | 13.41 | .46 |
| 1986 | 87.76 | | | | | 13.16 | .41 |
| 1987 | 85.96 | | | | | 12.89 | .37 |
| 1988 | 85.53 | | | | | 12.83 | .33 |
| 1989 | 85.40 | | | | | 12.81 | .30 |
| 1990 | 80.13 | | | | | 12.02 | .27 |
| 1991 | 86.13 | | | | | 12.92 | .26 |
| 1992 | 91.43 | | | | | 13.71 | .24 |
| 1993 | 90.30 | | | | | 13.55 | .22 |
| 1994 | 92.83 | | | | | 13.92 | .21 |
| 1995 | 89.96 | | | | | 13.49 | .20 |
| 1996 | 88.89 | | | | | 13.32 | .18 |
| 1997 | 88.82 | | | | | 13.32 | .17 |
| 1998 | 88.95 | | | | | 13.34 | .16 |
| 1999 | 88.58 | | | | | 13.29 | .16 |
| 2000 | 95.58 | | | | | 14.34 | .15 |

TABLE 6

TOTAL CEER FUNDS REQUIREMENTS FOR
OTEC, PHOTOVOLTAICS, BIOMASS, ETHANOL AND SOLAR STEAM R&D PROGRAMS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OTEC | | PHOTOVOLTAICS | | BIOMASS | | ETHANOL | | SOLAR STEAM | | | | | | |
| YEAR | OTEC | ADV. OTEC | PHOTOV. PROJECT | ADV. CONCEP. | DIRECT FIRING | ADV. CONCEP. | PROJECT | ADV. CONCEP. | PROJECT | ADV. CONCEP. | TOTALS SCENARIOS ( cols.) | BASE FUNDING REQ. (4) | TOTAL CEER FUNDING WITH SCENARIOS Col. 12 + Col. 13 | TAX LAW P. R. | EXTERNAL FUNDING (EXC. OF DOE PROJECTS) Col. 14-Col. 15 |
| 1980 | 3.11 | | .54 | | 2.16 | | .54 | | .10 | | 6.45 | 3.0 (1) | 9.45 | 6.45 | 3.0 (1) |
| 1981 | 3.97 | | .81 | | .59 | | 1.17 | | .23 | | 6.77 | 2.5 (2) | 9.27 | 6.77 | 2.5 (2) |
| 1982 | 3.93 | | 1.26 | | .50 | | 1.26 | | .38 | | 7.33 | 2.8 | 10.13 | 9.34 | 0.79 |
| 1983 | 4.09 | | 2.72 | | .54 | | 2.04 | | .68 | | 10.07 | 3.0 | 13.07 | 9.86 | 3.21 |
| 1984 | 5.24 | | 5.88 | | .59 | | 2.21 | | 1.47 | | 15.39 | 3.2 | 18.59 | 12.92 | 5.67 |
| 1985 | 5.86 | | 7.95 | | .64 | | 1.59 | .4 | 3.18 | | 19.62 | 3.5 | 23.12 | 13.41 | 9.71 |
| 1986 | | 1.71 | 8.55 | | | .80 | 1.28 | .86 | 8.55 | .8 | 22.55 | 3.8 | 26.35 | 13.16 | 13.19 |
| 1987 | | 1.85 | 7.40 | 1.85 | | 1.85 | .93 | 1.85 | 3.70 | 1.85 | 21.28 | 4.1 | 25.38 | 12.81 | 12.57 |
| 1988 | | 2.00 | 4.00 | 2.00 | | 2.00 | .50 | 2.00 | 4.00 | 2.00 | 18.50 | 4.4 | 22.90 | 12.02 | 10.88 |
| 1989 | | 2.16 | 1.62 | 2.16 | | 2.16 | .54 | 3.24 | 2.16 | 2.16 | 16.20 | 4.8 | 21.00 | 12.92 | 8.08 |
| 1990 | | 2.33 | | 2.33 | | 2.33 | .58 | 3.50 | 1.17 | 2.33 | 14.57 | 5.1 | 19.67 | 13.71 | 5.96 |
| Tot. | 26.2 | 10.05 | 40.73 | 8.34 | 5.02 (3) | 9.14 | 12.64 | 11.85 | 25.62 | 9.14 | 158.73 | 40.2 | 198.63 | 123.37 | 75.56 |

(1) Include Decontamination Program of Reactor at Mayaguez.
(2) Present CEER-DOE contract expires in FY 1981
(3) Latest estimate revised by Dr. A. G. Alexander is six million dollars.
(4) Projections after 1980 at 8% per year escalation.

The logic in selecting and setting the example scenarios has been based in the information, experience, and knowledge generated from R and D programs being 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 Federal Department of Energy. This low level of effort needs to be incremented considerably as has been indicated in order to produce meaningful results. Economic considerations and evaluations, potential capacity of the alternatives to meet the local energy needs and actual technical status and projections of the alternatives were taken into considerations. 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 of generating all the energy needs of Puerto Rico at some future date. Ocean based or floating type of plants in the southern Caribbean sea will have practically no impact on land utilization resources.

It is estimated that an OTEC-10 (40 MW plant) concept could be operational within 4 years. Preliminary economic calculations under certain assumption indicate PRWRA could afford $26.2 million dollars toward investment and the energy obtainable will be comparable in cost to one 450 MW coal plant located at Rincon with Flue Gas Desulfurization. It is suggested that the Puerto Rico Government contribute with the same funds for research and development. The project is estimated in $300 million including escalation and interest during construction. The Federal Government appropriation requirement is $247.6 million. A risk analysis consideration indicates an acceptable calculated risk for a public corporation.

Cost calculations were performed for 250 MW OTEC concept operational by the year 1990-91 and is shown to be 61% of the 450 MW coal plant cost of electricity. From this it is assumed that PRWRA can then finance completely such concepts from there on.

Such an agressive approach will definitely win the OTEC-10 concept for Puerto Rico over the Gulf States and Hawaii competition.

CEER requested R & D funding are indicated.

PHOTOVOLTAICS - Photovoltaics systems produce electricity by converting direct solar radiation into electricity using photo-electric cells. A large fraction of the energy is stored for use during non-daylight time. It is a complete static system with no known adverse environmental effects. The concept has enough potential to generate all the electric energy needs of Puerto Rico required by the year 2000 but it will require 90,000 - 100,000 acres of land - enormous farms of solar collectors cells and electronics.

The objectives for photovoltaics systems are defined in the program, its economics in the Puerto Rico scenario assesed and the R & D funds requirements are scheduled.

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

The economics of the project indicate that the energy costs will be 48% of the cost of a 450 MW coal plant, without the steam cogeneration portion. When the steam portion is added the economic attractiveness is even higher. These costs were determined for the P.R. scenario by using higher costs than the most recent basic data cost information. (1)

R&D funds need to be secured by CEER from the Puerto Rico Government for this project in the 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 R&D. A consortium of private enterprises, PRWRA and Fomento is suggested for the capital investment.

BIOMASS - Biomass is practically an agricultural enterprise. It 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 of Puerto Rico by the year 2000, but it will require 700,000-800,000 acres of land. One single 450 MW plant in operation by the year 1987, operating at 75% capacity factor could supply 13% of the electrical energy needs. Approximately 55,000-60,000 acres of land will be required to feed the plant.

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(1) Solar Electricity and Economic Approach to Solar Energy-Wolfgang Palz. Energy Development Program, Commission of European Communities, Brussels. UNESCO (1978).

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 boilers.

The economic analysis indicates that biomass is the costlier of the three alternatives, but still has a good economical advantage over a 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 bids specifications, enough data for specifying boilers to burn any of three fuels-oil, coal or biomass, and have all the logistics developed to burn biomass by the year 1986-87.

ETHANOL (MOTOR FUELS) - Ethanol can substitute gasoline or can be blended with gasoline to form a mixture as gasohol. Gasoline with 10% ethanol can be burned in motor vehicles without carburator modifications. For mixtures greater than 10% ethanol carburator modifications are required.

The consumption of gasoline in Puerto Rico during 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 in one billion gallons of gasoline (equivalents 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 83 % of the agricultural land in Puerto Rico. Cost are estimated to be competitive.

The R & D program objectives include the modification of a sugar mill to process 4000 tons of green sugar cane per day to produce approximately 6000 gals per day of ethanol and the extrapolation of the experience to 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-RUM Experimental Station and existing programs of development of saccharum hybrid species for increased yields. Total R & D Funds requirements are estimated at 12-13 millions excluding advanced concepts developments.

SOLAR STEAM - CEER has developed a highly efficient and inexpensive solar concentrator for producing industrial steam. A project is underway with Bacardi Distillers to produce solar steam at the Bacardi Rum Plant in Toa Baja (Palo Seco).

The production of ethanol as well as many other industrial processes, requires large amounts of steam. The production of 11% of the gasoline requirements for the year 1990 in ethanol will require approximately 1 million pounds of steam per day.

The program objective is to reduce the cost of ethanol (and 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 is $25 million excluding the development of advance concepts and related material development.

Total Budget

The total R & D budget which will be required by CEER from the Puerto Rico Government to agressively 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

## CONTENTS

CONTENTS Page No.

ANALYSIS OF EXAMPLES OF POSSIBLE SCENARIOS IN ENERGY AND ENVIRONMENT

I. OTEC

A. Program Objectives

1. Demonstration Plant in Operation by the year 1984-85.

A 40 MW plant should be planned so that extrapolation to at least a 5-fold scale could be attempted in a second generation plant. (10 MW Modules as per OTEC-10 DOE Program). This plant could generate about 1.1% of Puerto Rico energy needs by 1985.

2. Large Commercial Plant in Operation by the year 1990.

A 250 MW plant can be planned as an extrapolation of the Demonstration Plant.

The Demonstration Plant plus this plant can generate 7% of Puerto Rico energy needs by the year 1990.

3. Electrical System Addition on a competitive Basis.

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

B. OTEC Economics in Puerto Rico Scenarios

A 40 MW Demo Plant is estimated to cost about $5,000 per kw in 1978 dollars.

The estimated cost of energy can be roughly figured as follows:

1. Investment charges

   a. Project Investment

      (40,000) (5,000) (*) ------------------$200,000,000

   b. Yearly Investment charges

      at 10% cost of money ---------------- $ 20,000,000

   c. Yearly energy production

      at 85% capacity factor -------------- 298 x $10^6$ kwhr

   d. Investment charges in mills/

      kwhr -------------------------------- 67.1 mills/kwhr

2. 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 sea water 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 fueled Aguirre Units this would amount to approximately a staff of 170 men. At an average salary of $24,000 per man, (PRWRA average salary for power plants) the total staff salary would be:

(*) Feasibility Design Studies-Deep Oil Technology, Inc. Subsidiary Fluor Corporation. Unpublished. February 1979.

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 CEER Studies to be 2.33. Using the same ratio:

Total O and M

(2.33) (4,080,000) --------------- 9,506,000

O&M costs in mills/

kwhr ----------------------------- 31.9

3. Fuel Costs

The fuel costs are estimated to be 0.0

Total costs

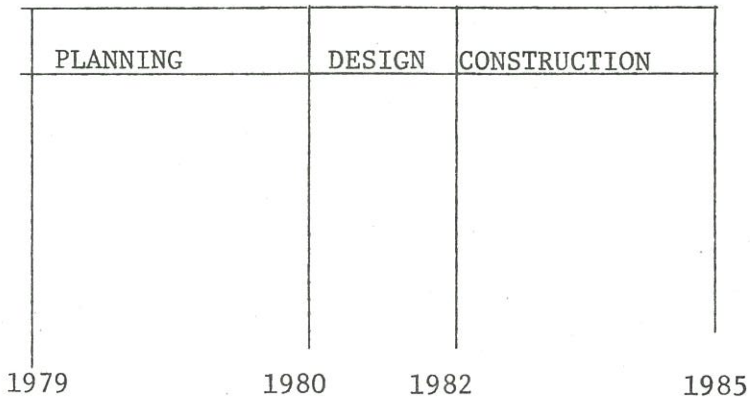
Demonstration Project-99.0 mills/kwhr

1978 dollars

1985 Total levelized costs (*)

This cost can be estimated by including escalation and interest during construction and levelizing the O&M cost during the plant lifetime. Assuming 7% escalation 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 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 separate CEER studies (Base line costs of commercially available energy alternatives in P.R. scenarios).




Escalation before construction = $(1.07)^{3}$

Escalation during construction = $(1.07)^{1.5}$

Interest during construction = $(1.07)^{1.5}$

Investment Escalation and Interest during construction -- Total Factor = 1.5

Operation Escalation at 7% /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 yield a levelizing factor of 1.75 (*)

Total levelized cost 1985

Investment charges:

(67.1) (1.5) -------------------- = 100.65

Operation and maintenance

(31.9) (1.5) x 1.75 ------------ = 83.7

40 MW OTEC Plant total levelized cost 184.3 mills/kwhr

---

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

Comparative Cost

The above cost can be compared with 92.5* mills/kwhr for a single 450 MW coal plant at Rincón with flue gas Desulfurization, 35 years life and operating at 75% capacity factor (the lower capacity factor is justified in an economic dispatch competition).

If the investment charge of the OTEC plant were 8.8 mills/kwhr the coal plant and the OTEC plant will have the same energy production costs of 92.5 mills/kwhr (total levelized cost during plant life); at 8.8 mills/kwhr the total yearly investment charge will be $2.62 millions (85% plant capacity factor) which justifies an investment of $26.2 millions in terms of 1985 dollars for PRWRA (or $17.4 millions in terms of 1978-79 dollars).

If the local Government matches these PRWRA funds for the R&D and subtructure requirements for a total contribution of $52.5 millions dollars (1985 dollars) from Puerto Rico, the Federal Government contribution to be sought is 247.5 million dollars (1985 dollars).

The fund distribution under this scheme could be:

---

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

CONTRIBUTION IN TERMS OF 1985 DOLLARS

| | | |
|---|---|---|
| PRWRA | $26.2 millions | - (plant investment) |
| P. R. Gov. | 26.2 millions | - (R&D) |
| Fed. Gov. | 247.6 millions | - (plant investment plus R&D) |
| | $300.00 millions | |

Operational Costs, mills per kw-hr

| | |
|---|---|
| PRWRA O&M | 83.7 (1) |
| PRWRA Investment | 8.8 |
| Sub-total | 92.5 (2) |
| P. R. Gov. Investment | 8.8 |
| Total P. R. | 101.3 |
| Federal Gov. | 83.0 |
| Total | 184.3 |

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

(1) This should be the maximum fixed by contract.

(2) This cost is equal to the energy production for the 450 MW coal plant discussed.

C. Approximate Cash Flow of Funds for Demo Project

| | P. R. Gov. | | PRWRA | | DOE | |
|---|---|---|---|---|---|---|
| Year | Year | Cummulative | Year | Cummulative | Year | Cummul. |
| 79 | --- | --- | --- | --- | --- | --- |
| 80 | 12 | 12 | 10% | 16 | 5% | 5 |
| 81 | 15 | 27 | 10% | 20 | 5% | 10 |
| 82 | 15% | 42 | 10% | 30 | 5% | 15 |
| 83 | 16 | 58 | 10% | 40 | 15% | 30 |
| 84 | 20% | 78 | 20% | 60 | 30% | 60 |
| 85 | 22 | 100% | 40% | 100 | 40% | 100 |

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

| Year | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|
| millions $ | 3.11 | 3.97 | 3.93 | 4.09 | 5.24 | 5.86 |

D. Extrapolation to Larger OTEC Plant -(Objective #2)

If the results of the Demo Project are satisfactory an extrapolation to build a 250 MW plant can be made with a high degree of accuracy. PRWRA can share a higher risk and the Government also.

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

The cost, of such a plant would be:

Investment charges:

$$\frac{(1500)^{*}(.1)}{(8760)\ (.85)} = 20.1 \text{ mills}$$

and in term of 1985 dollars = 30.2 mills

O&M costs will be assumed to be twice the staff cost (1978 dollars. )

$$\frac{(9{,}506{,}000) \times 2}{(250{,}000)\ (8760)\ (.85} = 10.2 \text{ mills/kwhr}$$

The levelized 1985 dollars will be:

$$(10.2)(1.5)(1.75) = 26.7 \text{ mills/kwhr}$$

Total cost is 56.9 mills/kwhr.

This is much lower than a fossil plant. PRWRA can finance it completely.

E. 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.

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

If we correlate as a zero order approximation the risks of a 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 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 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 worked out with more time and funds availability to CEER.

F. Advanced OTEC Concepts

After the first OTEC plants become operational R&D funds need to be secured for improvement of the existing embryonic technology and technical problems which might arise.

The foam OTEC concept under investigation by CEER should receive more detailed consideration then. A yearly assignment of \$1.0 million dollars (1979 basis) should be allocated for these purposes from 1986 on. At 8% escalation beginning in 1979, the following escalated allocations are computed.

ADVANCE OTEC CONCEPT FUNDING (\$MILLIONS)

| 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| 1.71 | 1.85 | 2.0 | 2.16 | 2.33 |

G. OTEC Environmental Research Scenario

The primary environmental issues associated with OTEC appear to be associated with:

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 Figure 1.

It is assumed that the funds for environmental research are included within the allocations already mentioned.

FIGURE I

| OTEC ENVIRONMENTAL PROJECT | | |
|---|---|---|
| OTEC TECHNOLOGY DEVELOPMENT | ENVIRONMENTAL INFORMATION NEEDED | ECONOMIC/ AESTHETIC CONSIDERATIONS |
| 1. Heat Exchanger Design | Biofouling Potential of different configurations, materials and modes of operation | Fouling influences efficiency, control methods cost |
| | Toxicity of control treatment | Potential reduction in fisheries |
| 2. Intake Design | Empingement potential | Obstruction reduces efficiency |
| | Entrainment potential | Potential reduction of biotic stocks reduction of fisheries |
| 3. Discharge Design | Field effects of different<br>Configurations and operations<br>Influence on currents<br>Influence on elemental distribution<br>Influence on tempeture | Redistribution of plankton reorientation of fish<br>Alteration of primary productivity-Food chain alterations leading to alterations in fisheries |
| | | Bioaccummulation of heavy metals in food chains leading to man |
| 4. Working Fluid Design | Field effects of leakage | Direct human injury |
| | Acute | Direct kill of organisms |
| | Chronic | Toxic or stimulatory effects, shifts of communities, losses of economic species, losses of aesthetically important |
| | | FORMS - impact on tourism |

## II. Photovoltaics

### A. Program Objectives

1. 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.

2. 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.

3. A cogeneration project to develop power and steam in an industrial park with the photovoltaic plants.

### B. Photovoltaic Economics in P. R. Scenario

1. Storage Criteria for P. R.

   It is assumed that 1/3 of the energy output of the photovoltaics during daylight time (8 hrs) will be delivered directly to the load and 2/3 of the energy generated during the same daylight time period will be stored

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*Note: The KW power value 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 "spinning" reserve capacity can be credited at the rate of capital cost of a conventional gas turbine.

To take care of absence of solar radiation during rainy days and 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 average insolation power of 7 KW-hr. per square meter per day, the required area for producing 1 KW of continuous power is:

$$3 \times \frac{8 \text{ kw-hr}}{(.045)\quad(7)} = 76.2 \text{ m}^2$$

The average insolation power per square meter is 7/24 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:

$$\text{Plant cost } \frac{\$}{KW} = \frac{\$ \text{ array cost}/m^2}{(\text{Plant eff}) \ (\text{Insolation power}/m^2}$$

$$+ \text{ Power Conditioning Cost } \frac{(\$)}{KW} \quad + \text{ Storage Cost } \frac{(\$)}{KW}$$

The following value are assumed from the present day technology and extrapolation of the same.

1977 dollars

(1) Total array efficiency = 4.5%

(2) Array cost

Solarcell cost(1) a): 1.0 mill/cm$^2$ or \$10.00/m$^2$

Wiring, structure,

installation cost/m$^2$ \$10.00(2)

Total array cost: \$20.00/m$^2$

(3) Storage cost(3) per kwh \$25

(4) Power conditioning cost per kwh: \$50

Plant Cost:

$$\frac{20}{(.045)(.292)} + (1.25)(25)(16) + 50$$

$$= 1522 + 500 + 50 = \$2072/kw$$

A \$200/kw could be credited due to twice available "spinning", reserve capacity, but will be neglected.

(1) Costs of \$5/m$^2$ predicted by Unesco for 1993.
(2) Same as cost predicted by Unesco.
(3) Costs of \$20.00 per kw-hr predicted by Unesco. Solar electricity and economic approach to solar energy-wolfgang palz energy development program Commision of European Communities Brussels. UNESCO 1978

3. Land and land rights charges:

The area for the plant (at a rate of 76.2 $m^2$ per KW is 4760 acres of land. An area of 5000 acres will be assumed at $2000 per acre the land cost is $10,000,000

Total Plant Cost:

| | | |
|---|---|---|
| Plant: | (250,000) (2072)= | $\$518 \times 10^6$ |
| Land: | 5,000 acreas a 2000 | $10 \times 10^6$ |
| | | $528 \times 10^6$ |

4. 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 that three weeks outage per year for photovoltaics is more than adequate, for forced and scheduled maintenance. This yields 94% capacity factor.

The investment charges at 10% cost of money and 94% capacity factor will be, in terms of 1977 dollars,

Investments charges in mills/kw h.

$$= \frac{(528) \quad (.1) \quad 10^6}{(8760)\ (250{,}000)\ (.94)} = \$.026$$

= 26 mills per kw-hr.

5. O&M Costs

O&M costs will be figured on the basis of an assumed plant staff. The area per KW of plant power is 76.2 $m^2$, therefore for a 250 MW module an area 4760 acres is required. Such large farm electronics, wiring, etc. will undoubtedly require some personnel. The following is assumed:

| | |
|---|---|
| 1 | Superintendent |
| 2 | Asst. Superintendent |
| 2 | Secretaries |
| 5 | Shift Supervisors |
| 10 | Shift operators |
| 2 | Electrical Engineers |
| 4 | Electricians |
| 2 | Electronic Engineers |
| 4 | Electronic Technicians |
| 1 | Instrument Engineer |
| 4 | Instrument Technicians |
| 1 | Mechanical Engineer |
| 3 | Mechanics |
| 2 | Clerks |
| 2 | Janitors |
| 5 | Gardeners and general landscapers |
| 20 | Security men (4 guards/shifts) |
| 5 | Shift chauffers |

1 Chauffer (regular hours)

3 Utility men (general)

2 Chemical Engineers (storage system)

8 Assistant Chemist (storage system)

1 Warehouse (spare parts) supervisor

2 warehouse clerks

1 Accountant

1 Purchaser, estimator

1 Clerk

93 Total

Ave. salary per man $24,000

Total salaries (24,000) (93) = 2,232,000

Assuming a factor of 1.0 for material replacement, etc., (and we believe this to be a very highly conservative assumption since photovoltaics is a static system).

Year Total OM $4, 464,000

$$\text{mills/kw} = \frac{4{,}464{,}000}{(250{,}000)(8760)(.94)} = 2.1 \text{ mills/kwh}$$

Total costs:

| | |
|---|---|
| Investment | 25.00 |
| O and M | 2.10 |
| Total (1978 dollars) | 27.1 mills/kwh |

1985 Dollars Cost (same factors as for OTEC Concept)

Total escalation for Investment (1979-1985) = 1.5

Total Escalation Factor Salaries (1979-1985) = 1.5

Levelizing factor for Plant Life for Escalation of

0 M = 1.75

| | | |
|---|---|---|
| Investment: | ( 26) (1.5) | 39.0 |
| Operation | (2.1) (1.5) (1.75) | 5.1 |
| | | 44.1 |

The cost of an equivalent coal plant is 92.5 mills/kwh (450 MW coal plant). The photovoltaic concept cost of energy is 48% of the cost of a 450 Mw coal plant.

The project should be suitable for commercial financing. The cost of the plant itself, estimated at $2072/kw can be twice or higher in cost and still the plant will be competitive with coal.

C. Cogeneration Photovoltaic Project

1. The economics of photovoltaics looks very promising in the P. R. Scenario. Since a photovoltaic installation takes a very large area a power plant site needs special consideration. An industrial park can very well 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 will offer

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 millions

   b. Cogeneration Cost Estimate (for evaluating level of R&D funds requirement only).

About 4 KW thermal power is produced for every 1.00 KWE 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/# is predicted together with an output of 151 kwe. There is no condensate return in the CEER project. For a large co-generation project, condensate will have to be returned.

Assuming 100°F condensate (obtainable with sea water once thru 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 co-generation project of 250,000 KW will be $3.15x10^9$ Btu/hr. (Note that the 250,000 KW is the ave. 24 hr. daily generation. The plant peak power capacity is three times higher and it stores all the 24 hr. energy in the assumed 8 hrs. of daylight).

At 80% capacity factor of the steam portion, yearly generation in thermal heat is 2.2 x $10^{13}$ Btu/year. Figuring conservatively $2.00 per MUBtu steam cost for a competitive project total gross yearly revenues are $44 million dollars.

The cogeneration project level of investment will therefore be in the order of 800-900 million dollars.

For any such project the R&D funds are figured at 6%. A level of $50 million dollars will be required for the R&D of such a project. Since the project is predicated under an economical basis, electricity being nearly half the cost of a coal plant, and steam cost much lower than from oil fired plant, the project can be funded by finantial enterprises on a commercial venture with PRWRA, Fomento and the P. R. Government. The project could be in operation by 1991-1992.

It is assumed that the P. R. Government can contribute with 50% of R&D Funds and the Federal Government with the remaining 50%.

P. R. Government assignment to this project is at a level of $25 millions (1979 basis).

The funding distribution is estimated as follows:

Research Funds for Photovoltaic Cogeneration $\$10^6$

| Year | | P. R. Funds | |
|---|---|---|---|
| | | Escalation | Actual |
| 1979 | - | --- | $\$10^6$ |
| 1980 | .50 | 1.08 | .54 |
| 1981 | .70 | 1.17 | .81 |
| 1982 | 1.00 | 1.26 | 1.26 |
| 1983 | 2.00 | 1.36 | 2.72 |
| 1984 | 4.00 | 1.59 | 5.88 |
| 1985 | 5.00 | 1.71 | 7.95 |
| 1986 | 5.00 | 1.85 | 7.40 |
| 1987 | 4.00 | 2.00 | 4.00 |
| 1988 | 2.00 | 2.16 | 1.62 |
| 1989 | .70 | 2.33 | --- |
| | 25.00 | | 40.73 |

D. Advanced Photovoltaics Concepts R&D

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 ($ Millions)

| 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|
| 1.85 | 2.0 | 2.16 | 2.33 |

E. Environmental Research Scenarios for Solar Photovoltaics

The primary environmental questions arising from this technology have to do with:

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

The first question requires research by resource economists and ecologists on the alternate uses of the land including evaluation of the possible destruction of rare and endangered life forms. The second research effort is primarily of the nature of an Environmental Impact Statement amd 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.

III. Biomass

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

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

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

3. Routine considerations to be given by PRWRA, under available technological know-how and market conditions, for evaluation of biomass on a competitive basis with other available alternatives for future electric system

additions beyond year 1990.

B. Biomass Economics in P.R. Scenarios

1. Pilot Boiler Plant: It is estimated that a two-year project demonstrating a 1000 tons per day pilot boiler plant, operational on a 12-months basis, will cost approximately $2.5 million in sugar-mill modification and logistics considerations plus $400,000 for one year operation and data gathering. About 1/3 of the investment will be in the biomass production phase, with special reference to off-season biomass production during a 4-month interval when bagasse will not be available. To produce this fuel the project will require land rentals in the order of 4,000 acres from the Department of Agriculture ($160,000/year for two years), irrigation water charges ($96,000/year for two years), purchase of four, 15-tower center pivot irrigation systems with pump and diesel engine installations ($380,000), and purchase of biomass harvesting equipment ($250,000). The Department of Agriculture budget is estimated at $512,000, and total production costs at $1,142,000. With the addition of unforseen cost items the total value of the 2-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 incident to:

a. Biomass production

b. Logistics of biomass harvesting, drying, storage, transportation, and incineration

c. Logistics and costs of biomass-delivery technology

d. Furnace performance and design

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

2. <u>Large Scale Plant Project</u>

Calculations for a 450 MW plant will be made in terms of 1985 dollars in order to compare with a similar coal fired unit.

Cost of power plant to burn coal and biomass

a. Investment charges

Coal Plant: $683/kw (1978 dollars)

Biomass plant:

A credit of $29/net kw can be given to the biomass plant for the unneeded equipment to burn no sulfur fuel but at the same time additional requirements will be necessary to burn both coals and biomass in the same boiler. It is assumed these two costs cancel out. The cost of the biomass burning plant is assumed to be the same as the coal plant.

Biomass power plant $683/kw (1978 dollars)

Investment charges same as for the coal plant 1985 dollars.....23.2 mills per kwh. (CEER energy studies).

b. Fuel Costs*

The fuel costs for biomass has been figured at $25(1) per ton delivered with a heat content of 15,000.000 BTU per ton. This yield $1.66 per millions Btu delivered fuel cost (Alex Alexander information). This cost is taken as 1979 fuel cost.

Assuming the same carrying charges for a biomass stock storage of 3 month as was assumed for coal, the carrying charges in biomass is 1/4 (1.66) (.1) or 4 cents per million BTU. The fuel costs at 1979 dollars level is therefore $1.70 per MMBTU including 3 month stock storage charges.

(1) This include $19.00 per ton production cost and $6/ton transportation costs. Drying of biomass will be on the field, cut and scattered. Bales or bundles are truck transported from the field to the electric power plant storage pile.

Levelized fuel cost 1985 dollar, 7 1/4 % escalation.

1985 Fuel Cost = $(1.70)(1.0725)^6$ MMBTU

Levelized (35 years) cost[1] = 1.75 (2.59)=$4.52/MMBTU.

With a plant heat rate of 10,000 Btu/kwhr (at 75% capacity factor).

Levelized fuel cost is 45.2 mills/per-hr.

c) Operation and Maintainance of the biomass operation will be taken equal to a coal plant less the operation maintainance of a FGD System. This estimated cost for O&M of Desulfurization System for coal plant[2] is = $STR\ (4P_1 + 10P_{sd})\ (LF)\ (1 + e)^Y$, where:

S = sulfur content of coal %/100

$P_1$ = price of limestone $/ton

TR = coal firing rate tons/hr.

$P_{sd}$ = price of sludge disposal #/ton

LF = plant coal factor

e = escalation

Y = years between time of estimate and beginning of operation.

(1) See CEER energy study. For levelization theory. This takes into account rising costs during plant life.

(2) 1 ton of sulfur requires 4 tons of limestone to produce 5 tons of dry sludge. This is combined with 5 tons of water to produce 10 tons of wet sludge, which requires disposal.

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

$Pl = P_s d$ = \$5.50/ton

S = .03

Tr = 200 tons/hr.

LF = 75%

Y = 7 years

e = .08

Substituting above figures in the formula gives, OM Desulfurization Plant = \$5.2 x $10^6$/year

The equivalent:

O&M cost in mills/kwh

for FGD System [(1)] is

$$\frac{5.2 \times 10^6}{(414.000)(.75)(8760)} = 1.91 \text{ mills/kwh}$$

The levelized 35 years OM for FGD System

Levelizes [(2)] OM cost FGD = (1.91)(1.75)= 3.35 $\frac{\text{mills}}{\text{kwh}}$

The total O&M levelized cost for a coal plant has been

| | |
|---|---|
| determined at -------- | 15.3 |
| less ---------- | 3.3 |
| cost O & M Biomass plant = | 12.0 mills/kw |

---

(1) Coal plant gross capacity is 450,000 kw. Net capacity will be 414,000 kw.

(2) 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.

1985 dollars is:

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

The comparable cost for a coal plant is 92.5 mills/kwhr

If the 80.4 mills/kwhr is corrected for the investment of 6.00 million (escalated) research funds invested in objective number one the correction is rather small. This correspond 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.

C. Energy Research Funds Requirements for Biomass(1)

| | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 |
|---|---|---|---|---|---|---|---|
| 1979 Base | | 2.0 | .50 | .4 | .4 | .4 | .4 |
| Escalation | 1.0 | 1.08 | 1.17 | 1.26 | 1.36 | 1.47 | 1.59 |
| Actual | | 2.16 | 0.59 | 0.50 | 0.54 | .59 | 0.64 |

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

D. Advanced Biomass Programs

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

ADVANCE BIOMASS PROGRAM DEVELOPMENT (MILLIONS $)

| 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| .8 | 1.85 | 2.0 | 2.16 | 2.33 |

E. Environmental Research Scenario for Biomass

The primary environmental issues associated with biomass fuel include:

1. Atmospheric emissions quality and quantity and potential toxicity to humans and other biota.
2. Residue disposal including possible beneficial uses of the ash as soil amendments.

Secondary environmental research which ought to be pursued is the possible coupling of sewage and other waste disposal to the rearing of biomass to ameliorate the fossil fuel subsidy required for high biomass yields.

3. Biomass production requires of land and site selection

to consider the possible alternatives uses of the land as in the case of photovoltaic generation.

It is difficult to estimate the cost of the research program for a biomass program. However, it will be 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 last fiscal year (1977-78) was 678 million gallons. [1] Gasoline consumption has been increasing and is presently increasing at the rate of 6.62% annually during the last twelve (12) years (1966-1978).

Ethanol could be produced from sugar cane as a motor fuel substitute at prices which will be competitive with gasoline by the time that a project to produce and market ethanol can become a reality. Predicted costs of ethanol are in the ranges of $1.00 to $1.25 per gallon.[2].

The equipment and facilities required are existent in Puerto Rico and they will require relatively small investments for conversion.

Cane juice is extracted by conventional sugar cane milling tandum. Juice is clarified in existing sugar mill

(1) Office of Energy data
(2) Sugar crops as a source of fuels - DOE - 1978

clarifiers and rotary vaccum cleaners and concentrated to about 20% total sugar content. From this step on a modification is required to the sugar mill. This modification involve yeast fermentation of the concentrated juices (fermentation can last 12-18 hours) and distillation of the same.

The cost of additions is in the order of 10-15% of the investment cost of a sugar mill.

In the sugar industry, bad weather or rain is a disaster to the sugar sucrose yield which reduces the revenues of the farmers. This is not so for alcohol production, and on the contrary it will be an asset.

The production of ethanol from sugar cane and of electricity from the sugar cane bagasse combined with the utilization of cane wastes is a very attractive program.

Ethanol yields today from sugar cane is 15.6 gallons per ton of green sugar cane. Today the average production of sugar cane in Puerto Rico is approximately 28 tons per acre. Alexander[1] has estimated that with a program partially optimized for biomass, yields as high as 29 tons of dry biomass (116 green tons per acre) are obtainable today. The ethanol yield would be 1800 gallons per acre.

Historically, experience has shown that yields under actual field conditions are much lower than under controlled

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

experimental facilities. It is therefore logical to expect a lower yield of ethanol per acre than the indicated figure.

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.

In order to produce the same gallons of ethanol equal to the same gallons of gasoline consumption last year in P. R. a total of 658,000 acres will be required. However, because of the lower heat content of ethanol this will be equivalent to only 60% of gasoline requirements. In addition this plantation could produce the total energy requirements by the ethanol plant and generate 50% of all the electricity requirements for the year 1982 by burning of baggasse. The acreage indicated represent 50 % of the total agricultural land in P.R.

The implications to the sugar industry and to the energy situation in P. R. could be very far reaching with such a potential program.

However, before any major scale operation is attemted it is necessary to develop realistic information pertaining to all the technical data and economic evaluation of a project to produce ethanol and biomass 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. Project operational by year 1983.

4. Large Scale Operation - Goal for 1986

   a. Ethanol production to equal 11% (1) of 1990 gasoline requirements. Investment cost for a new

---

(1) Assumes growth rate is reduced from 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.

facility (optimized) $225 million. Cost could be reduced to $60-105 million if existing sugar mills are considered. Economics studies of both alternatives are required.In addition optimization studies of ethanol for electric energy and electric cars scenarios need to be considered versus ethanol for cars.

b. Electrical generation with bagasse sufficient to feed 50% of the fuel requirements of 500 MW electrical machine at 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). Investment cost equivalent to a coal fueled electric plant, or $325 millions.

It was shown that the alternative of direct firing of biomass for electricity generation alone was competitive with coal. The combination should yield additional economic advantages.

The agricultural land requirement for both alternative combined will be twice the value estimated for biomass alone, because of the lower yields used.

C. 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 millions at 6-7% of cost is:

ETHANOL R&D PROGRAM FUNDS REQUIREMENTS

| Year | 1979 $ millions | Factor Escalation | Millions $ Actual |
|---|---|---|---|
| 1980 | .50 | 1.08 | .54 |
| 1981 | 1.00 | 1.17 | 1.17 |
| 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 | 1.59 |
| 1986 | 0.75 | 1.71 | 1.28 |
| 1987 | 0.50 | 1.85 | .93 |
| 1988 | 0.25 | 2.00 | .50 |
| 1989 | 0.25 | 2.16 | .54 |
| 1990 | 0.25 | 2.33 | .58 |
| | 8.50 | | 12.64 |

D. Advanced Concepts for Ethanol

Research for the production of ethanol at lower costs include increasing yield production, new methods of fermentation and distillation and new cycle optimization methods. Improvement of technical difficulties of the first ethanol plants will also require research funds. For these purposes 1/4 million dollars is assigned for 1985, 0.8 million for 1986, 1 million for 1987, and 1988, and 1.5 millions for 1989 and 1990 (1979 dollars). After escalating the indicated allocations the following results:

ADVANCED CONCEPT ETHANOL FUND REQUIREMENTS (ESCALATED) $ MILLIONS

| 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|---|
| .4 | 0.86 | 1.85 | 20 | 3.24 | 3.5 |

E. Environmental Research Scenario for Ethanol

The principal environmental impact of ethanol production is anticipated to be related to the disposal of the rum slops or "mostos" 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 mostos may be recovered for their energy and/or nutrient (fertilizer) value. This would enable the former waste to become a by-product.

## V. Solar Steam

### A. Potential and Economic Implications

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

Other industries using steam could probably achieve costs reduction 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 collection of solar energy is estimated at 55% at 350°F steam. It make use of direct as well as diffuse radiation of sunlight. It doesn't require daily tracking of the sun position and as such is a very low cost, efficient collector that can be used to produce solar steam a very low installed cost.

Presently there is a project to produce steam for the Bacardí 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 the 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 baggasse will be available for the electrical production.

Very rough calculations indicate that this project will cost $200-250 million dollars, could produce 10-15% profit on investment and sell the steam for half the cost of an equivalent oil fueled plant ($2 vs $4 per 1000 pounds of steam).

B. Program Objectives

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

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

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

C. R&D Funds Requirements

The R&D requirements are figured as follows:

| Year | (1979) $\$10^6$ | $Million (Escalation 8% Year) |
|---|---|---|
| 1980 | .1 | .1 |
| 1981 | .2 | .23 |
| 1982 | .3 | .38 |
| 1983 | .5 | .68 |
| 1984 | 1.0 | 1.47 |
| 1985 | 2.0 | 3.18 |
| 1986 | 5.0 | 8.55 |
| 1987 | 2.0 | 3.70 |
| 1988 | 3.0 | 4.00 |
| 1989 | 1.0 | 2.16 |
| 1990 | .5 | 1.17 |
| | 14.60 | 25.62 |

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)

| 1986 | 1987 | 1988 | 1989 | 1990 |
|---|---|---|---|---|
| .8 | 1.85 | 2.0 | 2.16 | 2.33 |

E. Environmental Research Scenarios for Solar Steam

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

## VI. SUMMARY TABLE OF TOTAL CEER FUNDING REQUIREMENTS FOR EXAMPLE SCENARIOS

TABLE 6 (Cols. 1-12)

TOTAL CEER FUNDS REQUIREMENTS FOR
OTEC, PHOTOVOLTAICS, BIOMASS, ETHANOL AND SOLAR STEAM R&D PROGRAMS
MILLION DOLLARS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | OTEC | | PHOTOVOLTAICS | | BIOMASS | | ETHANOL | | SOLAR STEAM | | |
| YEAR | OTEC (1) | ADV. OTEC | PHOTOV. PROJECT (2) | ADV. CONCEP. | DIRECT FIRING | ADV. CONCEP | PROJECT | ADV. CONCEP. | PROJECT | ADV. CONCEP. | TOTALS SCENARIOS |
| 1980 | 3.11 | | .54 | | 2.16 | | .54 | | .1 | | 6.45 |
| 1981 | 3.97 | | .81 | | .59 | | 1.17 | | .23 | | 6.77 |
| 1982 | 3.93 | | 1.26 | | .50 | | 1.26 | | .38 | | 7.33 |
| 1983 | 4.09 | | 2.72 | | .54 | | 2.04 | | .68 | | 10.07 |
| 1984 | 5.24 | | 5.88 | | .59 | | 2.21 | | 1.47 | | 15.39 |
| 1985 | 5.86 | | 7.95 | | .64 | | 1.59 | .4 | 3.18 | | 19.62 |
| 1986 | | 1.71 | 8.55 | | | .8 | 1.28 | .86 | 8.55 | .8 | 22.55 |
| 1987 | | 1.85 | 7.40 | 1.85 | | 1.85 | .93 | 1.85 | 3.70 | 1.85 | 21.28 |
| 1988 | | 2.00 | 4.00 | 2.00 | | 2.00 | .50 | 2.00 | 4.00 | 2.00 | 18.50 |
| 1989 | | 2.16 | 1.62 | 2.16 | | 2.16 | .54 | 3.24 | 2.16 | 2.16 | 16.20 |
| 1990 | | 2.33 | | 2.33 | | 2.33 | .58 | 3.50 | 1.17 | 2.33 | 14.57 |
| TOTALS | 26.2 | 10.02 | 40.73 | 8.34 | 5.02 (3) | 9.14 | 12.64 | 11.85 | 25.62 | 9.14 | 158.73 |

(1) Assumes Federal Government Participation in a ratio of 4.88 to 1.0, where the Puerto Rico participation is shared equally between PRWRA and the Government. Government Funds assigned for Research; PRWRA funds assigned to Capital Investment determined from equivalency of coal plant generation costs. (Escalation and interest during construction included in estimate).

(2) Assumes equal participation by the Federal Government (DOE).

(3) Latest estimate revised by Dr. A. G. Alexander is six million dollars.

# VII. SUMMARY TABLES

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

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | MILLION BARRELS OF OIL IMPORTS FOR | | | | | |
| YEAR | ELECTRICAL ENERGY (1) | GASOLINE & DIESEL(2) | INDUSTRY & OTHER(3) | TOTAL | ESTIMATED UNIT PRICE (4) $/BBL | TOTAL COST ($ Millions) |
| 1976 | 21.7 | 17.6 | 26.3 | 64.7 | | |
| 1977 | 23.0 | 18.2 | 21.5 | 62.7 | | |
| 1978 | 24.5 | 16.5 | 23.9 | 65.0 | | |
| 1979 | 26.0 | 17.0 | 25.1 | 68.1 | 14.70 | 1001. |
| 1980 | 27.5 | 17.9 | 26.3 | 71.7 | 16.78 | 1203 |
| 1981 | 29.0 | 18.5 | 27.7 | 75.2 | 19.17 | 1442 |
| 1982 | 29.7 | 19.0 | 29.1 | 77.8 | 21.30 | 1704 |
| 1983 | 31.9 | 19.8 | 30.5 | 82.2 | 25.00 | 2055 |
| 1984 | 33.6 | 20.5 | 32.0 | 86.1 | 28.55 | 2458 |
| 1985 | 35.3 | 21.0 | 33.6 | 89.9 | 32.70 | 2939 |
| 1986 | 36.7 | 21.4 | 35.3 | 93.4 | 36.29 | 3390 |
| 1987 | 37.9 | 21.9 | 37.1 | 96.9 | 40.28 | 3903 |
| 1988 | 42.2 | 22.5 | 38.9 | 103.6 | 44.72 | 4633 |
| 1989 | 44.8 | 23.1 | 40.9 | 108.8 | 49.60 | 5396 |
| 1990 | 47.4 | 23.6 | 42.9 | 113.9 | 55.00 | 6266 |
| 1991 | 50.8 | 24.0 | 45.1 | 119.9 | 58.75 | 7044 |
| 1992 | 53.4 | 24.5 | 47.3 | 125.2 | 62.75 | 7856 |
| 1993 | 56.0 | 25.1 | 49.7 | 130.8 | 67.00 | 9295 |
| 1994 | 59.1 | 25.7 | 52.2 | 137.0 | 71.50 | 9796 |
| 1995 | 62.0 | 26.0 | 54.8 | 142.8 | 76.50 | 10924 |
| 1996 | 65.0 | 26.4 | 57.5 | 148.9 | 81.12 | 12078 |
| 1997 | 68.1 | 26.7 | 60.4 | 155.2 | 86.00 | 13347 |
| 1998 | 71.5 | 27.4 | 63.4 | 162.3 | 91.15 | 14793 |
| 1999 | 74.1 | 27.9 | 66.6 | 168.6 | 96.62 | 16290 |
| 2000 | 77.6 | 28.1 | 69.9 | 175.6 | 102.6 | 18016 |
| TOTAL | | | | | | $155,829 |

(1) Statistical Correlations between population and GNP and between GNP and Electrical Energy Generation. Correlation 99%. See Appendix E

(2) Gasoline Consumption growth projected conservatively between 2 1/2 - 3% per year vs. 6.6% 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 proces escalation indicated is approximately 1980-85: 14.3%/year; 1985-90: 11% year; 1990-95: 6.8%/year and 1995-2000: 6% year.

TABLE 3A

SCHEDULE OF PROPOSED SCENARIOS PROGRAM OBJECTIVES

| YEAR | (1) OTEC | (2) PHOTOVOLTAICS ELECTRIC [(1)] ELEC.MW | (3) PHOTOVOLTAICS STEAM $10^6$BOil | (4) BIOMASS | (5) ETHANOL %ofgas.req.) | (6) DIRECT SOLAR STEAM (OIL SAV.) MILLION BBL OIL: ETHANOL PLT. | (7) DIRECT SOLAR STEAM (OIL SAV.) MILLION BBL OIL: IND. STEAM |
|---|---|---|---|---|---|---|---|
| 1979-84 | | | | | | | |
| 1985 | 1-40MW | | | | | | |
| 1986 | | | | | 11% | 2.0 | |
| 1987 | | | | 450MW | | 2.0 | |
| 1988 | | | | | 22% | 4.0 | 2.0 |
| 1989 | | | | 450MW | | 4.0 | 2.0 |
| 1990 | 1-250MW | | | | 33% | 6.0 | 4.0 |
| 1991 | | | | | | 6.0 | 4.0 |
| 1992 | | | | | | 6.0 | 4.0 |
| 1993 | | 250MW | 3.7 | | | 6.0 | 4.0 |
| 1994 | | | | | | 6.0 | 4.0 |
| 1995 | 1-500MW | | | | | 6.0 | 6.0 |
| 1996 | | 250MW | 3.7 | | | 6.0 | 6.0 |
| 1997 | 1-500MW | | | | | 6.0 | 6.0 |
| 1998 | 1-500MW | | | | | 6.0 | 6.0 |
| 1999 | 1-500MW | | | | | 6.0 | 6.0 |
| 2000 | | | | | | 6.0 | 6.0 |

(1) At least 9-500MW base load units will be required in the period considered. Additional fossil fueled units needs to be added.

TABLE 3B

POSSIBLE MILLIONS BARRELS OIL SAVED WITH PROPOSED SCENARIOS

| YEAR | (1) OTEC | (2) PHOTOVOLTAICS ELECTR. | (3) PHOTOVOLTAICS STEAM | (4) BIOMASS | (5) ETHANOL Gasohol | (6) ETHANOL Electric(2) | (7) STEAM | (8) TOTALS |
|---|---|---|---|---|---|---|---|---|
| 1985 | .53 | | | | | | | 0.53 |
| 1986 | .53 | | | | 1.87 | 1.24 | 2.0 | 5.64 |
| 1987 | .53 | | | 5.3 | 1.87 | 1.24 | 2.0 | 10.94 |
| 1988 | .53 | | | 5.3 | 3.74 | 1.25 | 6.0 | 18.07 |
| 1989 | .53 | | | 10.6 | 3.74 | 1.25 | 6.0 | 23.40 |
| 1990 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1991 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1992 | 3.86 | | | 10.6 | 5.61 | 3.7 | 10.0 | 33.77 |
| 1993 | 3.86 | 3.53 | 3.7 | 10.6 | 5.61 | 3.7 | 10.0 | 40.50 |
| 1994 | 3.86 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 10.0 | 44.17 |
| 1995 | 10.53 | 3.53 | 3.7 | 10.6 | 7.48 | 5.0 | 12.0 | 52.84 |
| 1996 | 10.53 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 60.01 |
| 1997 | 17.20 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 66.38 |
| 1998 | 23.84 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 73.35 |
| 1999 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |
| 2000 | 30.54 | 7.00 | 7.4 | 10.6 | 7.48 | 5.0 | 12.0 | 80.02 |

(2) Estimated 80 kwhr per ton of (51% moisture) baggase.

TABLE 4

POTENTIAL, "ENERGY AND COST REDUCTIONS"
WITH EXAMPLE SCENARIOS

| (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|
| | CONSUMPTION MILLION BARRELS OIL | | REDUCTION $10^6$ BBLS | MILLION DOLLARS | FRACTION (%) OF SCENARIOS |
| YEAR | NO SCENARIOS | WITH EXAMPLE SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS WITH SCENARIOS | SAVINGS OF TOTAL-NON SCENARIOS |
| 1985 | 89.9 | 89.37 | 0.53 | 17.33 | 0.5% |
| 1986 | 93.4 | 87.76 | 5.64 | 204.67 | 6% |
| 1987 | 96.9 | 85.96 | 10.94 | 440 | 11% |
| 1988 | 103.6 | 85.53 | 18.07 | 808 | 17% |
| 1989 | 108.8 | 85.40 | 23.40 | 1,160 | 21% |
| 1990 | 113.9 | 80.13 | 33.77 | 1,857 | 30% |
| 1991 | 119.9 | 86.13 | 33.77 | 1,984 | 28% |
| 1992 | 125.2 | 91.43 | 33.77 | 2,119 | 27% |
| 1993 | 130.8 | 90.30 | 40.50 | 2,714 | 29% |
| 1994 | 137.0 | 92.83 | 44.17 | 3,158 | 32% |
| 1995 | 142.8 | 89.96 | 52.84 | 4,042 | 37% |
| 1996 | 148.9 | 88.89 | 60.01 | 4,868 | 40% |
| 1997 | 155.2 | 88.82 | 66.38 | 5,709 | 43% |
| 1998 | 162.3 | 88.95 | 73.35 | 6,886 | 47% |
| 1999 | 168.6 | 88.58 | 80.02 | 7,732 | 47% |
| 2000 | 175.6 | 95.58 | 80.02 | 8,210 | 46% |
| TOTALS | 2072.8 | 1415.62 | 657.18 | 51,909.0 | 36% |
| COST $\$10^6$ | :145,966 | | | | |

TABLE 5

POSSIBLE CEER REVENUES FROM FUELS TAX R&D LAW

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| | MILLION BARRELS | 1.5c/$10^6$ BTU TAX | | 2c/$10^6$ BTU TAX | | 2.5c/$10^6$ BTU TAX | |
| YEAR | CONSUMPTION with SCENARIOS | $$10^6$ | % | $$10^6$ | % | $$10^6$ | % |
| 1980 | 71.70 | 6.45 | 0.53 | | | | |
| 1981 | 75.20 | 6.77 | 0.47 | | | | |
| 1982 | 77.80 | | | 9.34 | 0.55 | | |
| 1983 | 82.20 | | | 4.86 | 0.48 | | |
| 1984 | 86.10 | | | | | 12.92 | .53 |
| 1985 | 89.37 | | | | | 13.41 | .46 |
| 1986 | 87.76 | | | | | 13.16 | .41 |
| 1987 | 85.96 | | | | | 12.89 | .37 |
| 1988 | 85.53 | | | | | 12.83 | .33 |
| 1989 | 85.40 | | | | | 12.81 | .30 |
| 1990 | 80.13 | | | | | 12.02 | .27 |
| 1991 | 86.13 | | | | | 12.92 | .26 |
| 1992 | 91.43 | | | | | 13.71 | .24 |
| 1993 | 90.30 | | | | | 13.55 | .22 |
| 1994 | 92.83 | | | | | 13.92 | .21 |
| 1995 | 89.96 | | | | | 13.49 | .20 |
| 1996 | 88.89 | | | | | 13.32 | .18 |
| 1997 | 88.82 | | | | | 13.32 | .17 |
| 1998 | 88.95 | | | | | 13.34 | .16 |
| 1999 | 88.58 | | | | | 13.29 | .16 |
| 2000 | 95.58 | | | | | 14.34 | .15 |

TOTAL CEER FUNDS REQUIREMENTS FOR
OTEC, PHOTOVOLTAICS, BIOMASS, ETHANOL AND SOLAR STEAM R&D PROGRAMS

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OTEC | | PHOTOVOLTAICS | | BIOMASS | | ETHANOL | | SOLAR STEAM | | | | | | |
| YEAR | OTEC | ADV. OTEC | PHOTOV. PROJECT | ADV. CONCEP. | DIRECT FIRING | ADV. CONCEP. | PROJECT | ADV. CONCEP. | PROJECT | ADV. CONCEP. | TOTALS SCENARIOS ( cols.) | BASE FUNDING REQ.(4) | TOTAL CEER FUNDING WITH SCENARIOS Col. 12 + Col. 13 | TAX LAW P. R. | EXTERNAL FUNDING (EXC. OF DOE PROJECTS Col. 14-Col. 15 |
| 1980 | 3.11 | | .54 | | 2.16 | | .54 | | .10 | | 6.45 | 3.0(1) | 9.45 | 6.45 | 3.0(1) |
| 1981 | 3.97 | | .81 | | .59 | | 1.17 | | .23 | | 6.77 | 2.5(2) | 9.27 | 6.77 | 2.5(2) |
| 1982 | 3.93 | | 1.26 | | .50 | | 1.26 | | .38 | | 7.33 | 2.8 | 10.13 | 9.34 | 0.79 |
| 1983 | 4.09 | | 2.72 | | .54 | | 2.04 | | .68 | | 10.07 | 3.0 | 13.07 | 9.86 | 3.21 |
| 1984 | 5.24 | | 5.88 | | .59 | | 2.21 | | 1.47 | | 15.39 | 3.2 | 18.59 | 12.92 | 5.67 |
| 1985 | 5.86 | | 7.95 | | .64 | | 1.59 | .4 | 3.18 | | 19.62 | 3.5 | 23.12 | 13.41 | 9.71 |
| 1986 | | 1.71 | 8.55 | | | .80 | 1.28 | .86 | 8.55 | .8 | 22.55 | 3.8 | 26.35 | 13.16 | 13.19 |
| 1987 | | 1.85 | 7.40 | 1.85 | | 1.85 | .93 | 1.85 | 3.70 | 1.85 | 21.28 | 4.1 | 25.38 | 12.81 | 12.57 |
| 1988 | | 2.00 | 4.00 | 2.00 | | 2.00 | .50 | 2.00 | 4.00 | 2.00 | 18.50 | 4.4 | 22.90 | 12.02 | 10.88 |
| 1989 | | 2.16 | 1.62 | 2.16 | | 2.16 | .54 | 3.24 | 2.16 | 2.16 | 16.20 | 4.8 | 21.00 | 12.92 | 8.08 |
| 1990 | | 2.33 | | 2.33 | | 2.33 | .58 | 3.50 | 1.17 | 2.33 | 14.57 | 5.1 | 19.67 | 13.71 | 5.96 |
| Tot. | 26.2 | 10.05 | 40.73 | 8.34 | 5.02(3) | 9.14 | 12.64 | 11.85 | 25.62 | 9.14 | 158.73 | 40.2 | 198.63 | 23.37 | 75.56 |

(1) Include Decontamination Program of Reactor at Mayaguez.
(2) Present CEER-DOE contract expires in FY 1981
(3) Latest estimate revised by Dr. A. G. Alexander is six million dollars.
(4) Projections after 1980 at 8% per year escalation.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX E

# LONG RANGE FORECAST OF ENERGY NEEDS IN PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX E

LONG RANGE FORECAST OF PUERTO RICO'S ENERGY NEEDS

I. ELECTRICAL ENERGY FORECAST

A. General

The problem of forecasting long range estimates of energy use is a rather difficult task because of all the uncertainties involved in the development of new technologies and changing habits which will affect considerably the estimates. An attempt has been made to forecast for a length of period in which present embryonic technolgies could be extrapolated in a qualitative sense. A 40 year period, up to the year 2000, is believed to be long enough to provide for such an extrapolation and at the same time provide energy planners with an overview of the next four decades for the adequate focusing of energy alternatives.

CEER interest is mainly in the energy or fuel alternatives scenarios which are required to power the Puerto Rico 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 were used.(1) The approach adapted was as simple as possible so as not to complicate the prediction with complex relations and hypotheses, such as postulating saturation functions, etc.

(1) Statistical Methods for Decision Making, W.A. Chance 1969. IRWIN-DORSEY LMTD., Mokeleton, Ontario.

The prediction of energy generation requirement is recognized to be based on two main factors:

1- Population

2- Economic welfare or income per capita of the population.

The above factors were be analyzed statistically in making the prediction. After the mathematical relationship were established, then judgement of past experience and insight of new technologies and changing habits were considered to select the most appropriate relationship.

The energy prediction was be based simply on a correlation between total GNP at constant prices and electrical energy. The GNP was be 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, GNP up to the year 1983. Our predictions will be, therefore, somewhat uncertain for the period 2000-2020.

B- Population

Population is a very sensitive variable in the prediction of energy needs. Different government programs, economic welfare, social and religious groups' attitudes may influence to a certain degree, the population growth. Meléndez (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 population is doubled in

(2) Conferencia sobre Economía y Población, Dr. James A. Santiago Meléndez Serie de Conferencias y Foros: Núm. 4 Departamento de Economía, Universidad de Puerto Rico, Río Piedras, Puerto Rico.

less than 35 years, or to a slow population growth rate such as doubling of population every 200 years. Doubling times of the order 50 years in the population is considered moderate and adequate to help the economic growth.

A rapid population growth rate causes severe impact on the nation's substructure, the balances of resources and requires higher investments from outside sources, etc. A very slow population growth rate on the other hand can create a problem as the population matures in age and there are not 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. Planning Board Population predictions on a city by city basis up to the year 2020 has 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 i.e, year less 1960. Coefficient of determination of above equation, $r^2 = 0.98$, 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 an adequate economical growth as pointed out by Meléndez.(3)

An exponential regression of population was also attempted. The exponential relation gave 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 government as previously indicated it was discarded. The exponential relationship was: population equals to 2308.66, times "e" elevated to the exponent 0.02x, x having the same meaning as before.

The predicted population for the year 2020 with this exponential relation was 7,300,580. This was discarded in favor of the more appropriate linear correlation indicating a 6,070,110 population in the year 2020.

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(3) Op. Cit.

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

TABLE I - POPULATION

BY LINEAR REGRESSION MODEL

| YEAR | POPULATION (MILLIONS) |
|---|---|
| 1979 | 3.47 |
| 1980 | 3.53 |
| 1981 | 3.65 |
| 1982 | 3.72 |
| 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 |

C- Economic Welfare

It will be assumed in the 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 should then reflect a yearly increase of at least equal to the population growth rate in 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 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 satisfactority 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 - ECON. INDEXES

Planning Board Prediction (of GNP)

Current Dollars ($ thousands)

| | 1979 | 1980 | 1981 | 1982 | 1983 |
|---|---|---|---|---|---|
| Current $ | 9835.0 | 10750 | 11,693 | 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 incrementl 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.

These data together with historical data back to the year 1962 were then retrieved by statistical methods. Four types of regression analysis were tried, including, linear, exponential, logarithmic and power. The best fit correlated with a 97.5% correlation coefficient or 95% coefficient of determination. This fit was: $y = 546.87\ x^{.27}$, where: y = GNP/capita in constant 1954 dollars, x = year - 1960.

Predicted values with above equation indicate yearly improvements in GNP/capita at constant dollars of the order 0.5 to 1.5 to 1.0% which is considered adequate and on the low side.

The predicted GNP per capita at constant dollars was multiplied by the predicted population to obtain the total predicted GNP at constant dollars.

D- 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 : Coeff. of determination 98%; doubling Time: 11 years

3) Log Correlation : Coeff. of determination 97%; doubling Time: over 40 years

4) Exp. Correlation : Coeff. of determination 93%; doubling Time: 5 years

A statistical test indicated excellent correlations on 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. It is felt however, that new technologies and new consumer goods will impact beyond present expectations on further needs of electric power. One example, could be the development of urban electrical vehicles requiring nightly battery charging. This requirement might offset the leveling of power growth as predicted by a linear relationship. Also, the development of new technologies for producing electrical power from renewable sources (solar) might bring down costs enhancing an increase in the demand. We, therefore, feel that the power fit represents an adequate description of future electrical generation production.

The power fit is given by, $\text{KWHR gen} = (0.0012294)(\text{GNP})^{1.96} \times 10^6$ where the unit for GNP is million dollars at 1954 constant dollars.

Table III indicates the correlation data for population, GNP 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 2000 is 38,261 x $10^6$ KWHR generation which is comparable to our prediction of 42,910 x $10^6$ KWHR within 5% difference.

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

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

## TABLE III

## GNP POPULATION AND ELECTRICAL PRODUCTION CORRELATION DATA

## CONSTANT PRICES (1954)

| Fiscal Year | GNP/capita $/Capita | Population Thousands | GNP $ millions | Electric Prod. 106 KW-hr |
|---|---|---|---|---|
| 62 | 694 | 2,228 | 1,683.9 | 2,570.7 |
| 63 | 736 | 2,473 | 1,820.7 | 2,934.5 |
| 64 | 768 | 2,523 | 1,938.9 | 3,403.2 |
| 65 | 817 | 2,568 | 2,099.2 | 3,819.2 |
| 66 | 861 | 2,603 | 2,240.6 | 4,429.8 |
| 67 | 892 | 2,623 | 2,239.4 | 5,040.7 |
| 68 | 927 | 2,650 | 2,455.3 | 5,770.9 |
| 69 | 1000 | 2,685 | 2,684.0 | 6,654.5 |
| 70 | 1070 | 2,711 | 2,901.4 | 7,539.5 |
| 71 | 1120 | 2,747 | 3,075.6 | 8,513.3 |
| 72 | 1139 | 2,823 | 3,215.9 | 10,228.0 |
| 73 | 1186 | 2,910 | 3,450.3 | 11,778.0 |
| 74 | 1168 | 2,991 | 3,493.6 | 12,329.3 |
| 75 | 1113 | 3,076 | 3,424.7 | 12,208.9 |
| 76 | 1101 | 3,167 | 3,487.3 | 12,349.8 |
| 77 | 1116 | 3,266 | 3,644.4 | 13,290.4 |
| 78 | 1150 | 3,338 | 3,837.5 | 13,755.9 |
| 79 | 1166.4* | 3,470 | 4,047.4* | 14,611.2 |
| 80 | 1217.8* | 3,530* | 4,298.8* | 15,429.6 |
| 81 | 1246.52* | 3,650* | 4,549.7* | 16,307.2 |
| 82 | 1294.1* | 3,720* | 4,814.0* | 17,197.5 |
| 85 | 1310.9 | 3,920* | 5,138.7 | 23,684 |
| 90 | 1377.5 | 4,260* | 5,868.15 | 30,734 |
| 95 | 1436.4 | 4,520* | 6,492.53 | 37,483 |
| 2000 | 1489.4 | 4,670* | 6,955.50 | 42,910 |
| 2005 | 1537.8 | 5,090 | 7,827.40 | 54,106 |
| 2010 | 1582.5 | 5,420 | 8,577.15 | 64,748 |
| 2015 | 1624.0 | 5,750 | 9,338.00 | 76,505 |
| 2020 | 1662.8 | 6,070 | 10,093.20 | 89,120 |

* Planning Board Predictions

## REFERENCES


1- Statistical Methods for Decision Making, W. A. Chance 1969.
IRWIN-DORSEY LMTD, Mokeleton, Ontario.

2- Conferencia sobre Economía y Población, Dr. Jaime A. Santiago Meléndez, Serie de Conferencias y Foros: Núm. 4 Departamento de Economía, Universidad de Puerto Rico, Río Piedras, Puerto Rico.

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

K&E 10 X 10 TO THE CENTIMETER KEUFFEL & ESSER CO. 46 1513

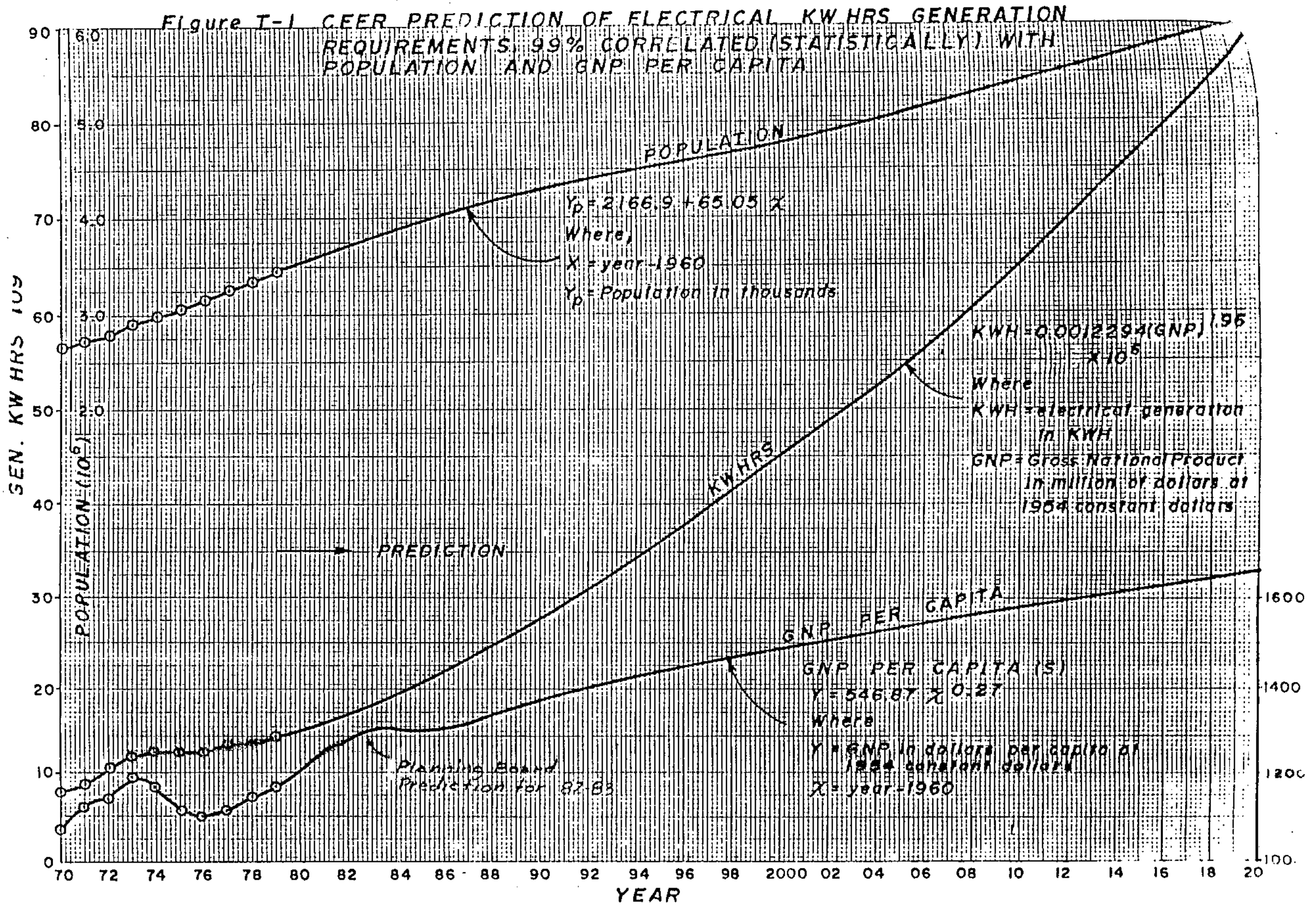


Figure T-1 CEER PREDICTION OF ELECTRICAL KW HRS GENERATION REQUIREMENTS 99% CORRELATED (STATISTICALLY) WITH POPULATION AND GNP PER CAPITA

APPENDIX F

PROPOSED PUERTO RICO RESEARCH INSTITUTE

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

PUERTO RICO RESEARCH INSTITUTE

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

The Institute will provide specialized research and advisory services, by contract, to solve specific problems for industry, government, foundations and individuals.

The Institute will undertake pure as well as applied research indicated above.

The Institute shall be formed by contributing members mainly private organizations, industry, professional organizations, etc., and the government. The greatest bulk of the research work is expected to come from Puerto Rican Government sponsored contracts on energy research field for which adequate cooperation needs to be obtained from government by legislative action.

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

The Governing Board will select its President, Vice-President, and Secretary between themselves. The Governing Board shall meet at least once a month.

The Governing Board will have no salary. A per diem will be assigned for every meeting of $35 per meeting, plus travelling and other out-of-pocket expenses.

Any person of recognized moral standing and any organization or corporation doing legitimate business can apply for membership. All Institute members will have a yearly dues of $500. A down payment of 50 years dues ($25,000) will make the member a Benefactor Life Member. A down payment of 30 years dues ($15,000) will make the member a Life Member. Organizations or Corporations members will have only one representative with voice and vote. Each active member will have only one vote.

Membership privilege include participation with voice and vote on all Institute members meeting. They will receive copies of all unclassified Institute research project reports. Short general consulation and orientation from staff members is provided free of charge, and free use of Institute library will be provided.

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

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

Each government member indicated above will have one vote at members meetings making a total of 11 voting members for the government by legislative action. Other government agencies or institutions could apply for membership on a voluntary basis.

Government contribution by State Legislative Assembly authorizations must be sought for permanent facilties and laboratory equipment. Some help on operating funds for initial operations may probably be required. All equipment and property bought with Government funds will remain property of the Government and will be identified properly and taken care and disposed of as regulated by the Office of the Controller. All direct work performed for the Government will be by contract and such contract should reflect corresponding cost reduction for the use of government property.

No official or member or other party shall pccrue financial benefit since this is a non-profit corporation. However, research projects shall be performed at cost plus some Institute benefit to provide for self expansion of permanent facilities purchase of additional laboratory equipment, etc.

It is expected that the majority of members will be from private institutions and local industry.

The members will have an annual business meeting in the month of November and will appoint the Governing Board or whatever vacancy there occurs in the Governing Board. No employee of the Institute who simultaneously holds membership in the Institute will be permitted to vote in the selection of the Governing Board Members.

The Governing Board will preside at the member meetings and discuss the affairs of the Institute including Financial, Technical, Research

Projects, Topics, etc. At least two members meetings shall be held yearly.

The Governing Board will appoint the Executive Officers. Executive Officers will be employees of the Institute. They include the President and the four Vice Presidents of the Institute as follows:

1) President
2) Executive Vice President-Contractual Relationships and Fund Raising
3) Vice President-Engineering and Research
4) Controller
5) Personnel Officer

There shall be as many Divisions as found necessary. All changes in organizational matters have to be approved by the Governing Board. The President will appoint the Division Heads in consultation with the Vice Presidents and with the endorsement of the Governing Board.

All officers of the company shall be full time employees and they will have a salary as approved by the Governing Board. No officer can be removed from office unless proven of misconduct, negligence, inadequate discharge of duties, incompetence, etc.

All research projects sponsored by public funds shall be for the benefit of the government and the people of Puerto Rico. All research project carried with private funds shall be proprietary if so desired by the sponsoring organization.

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX G

THE NEED TO EXPLORE ALTERNATIVE ENERGY SOURCES FOR PUERTO RICO

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

8 April 1979

APPENDIX G

THE NEED TO EXPLORE ALTERNATIVE ENERGY SOURCES FOR PUERTO RICO

## I. INTRODUCCION

La cuadruplicación de los precios del petróleo por parte de la Organización de Países Exportadores de Petróleo (OPEP) a fines del año 1973 ha tenido un impacto profundo y permanente en las economías de casi todos los países del mundo incluyendo a Puerto Rico El impacto inicial fue un fuerte aumento en los precios de casi todos los bienes y servicios intermedios y los que van al consumidor final. El aumento de los precios aumentó los costos de producción de casi todos los sectores industriales reduciendo así la capacidad productiva de estos. La inflación que fue seguida por una severa recesión aumentó la tasa de desempleo reduciendo la producción actual y aumentando el "gap" entre esta última y el producto potencial que se obtendría de la economía estar usando todos sus recursos a casi su capacidad Se estima que el aumento en el precio de la energía redujo en forma permanente la capacidad económica, o la producción potencial de la economía de los Estados Unidos en cerca de un cinco porciento (1) reduciendo también en forma drástica la productividad del capital y la mano de obra.

La producción de un sector industrial, o de la economía en su totalidad, dependerá del acervo (stock) de capital, de la mano de obra, otros recursos (como la energía) y de cómo se combinan estos

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(1) Robert H. Rasche y John A. Tatom, "The Effects of the New Energy Regime on Economic Capacity, Production and Prices", Federal Reserve Bank of St. Louis, Review (May, 1977).

recursos (la tecnología). Los precios que se paguen por estos recursos determinan los costos de producción. De tal forma que el aumento en el precio de energía afectó los costos de producción (dada la tecnología) lo cual tuvo un impacto adverso sobre la producción. En cuanto se afectaron los costos de producción va a estar determinado por la participación ("share") del recurso (el cual fue objeto del aumento en precio) en los costos totales.

No existe la menor duda de que si no existe expectativa alguna de que hayan los precios del petróleo (y las empresas quieren minimizar sus costos) la alternativa será el cambio tecnológico y esto en términos del recurso de energía implica el buscar fuentes alternas de este recurso.

## El Costo de Energía por Sector Industrial en Puerto Rico y Capacidad Productiva

Los sectores industriales de Puerto Rico necesitan del insumo de energía (combustible y electricidad) para llevar a cabo su producción. También el consumidor final demanda productos derivados del petróleo. En otras palabras que la industria de productos de petróleo vende su producto a otras industrias para ser usado como insumo intermedio, y a los consumidores finales. De igual forma lo hace el sector industrial productor de electricidad. La Tabla I ilustra la demanda que hacen los diversos sectores industriales y el consumidor final de productos de petróleo en base al cuadro de relaciones interindustriales de 1972 publicado por la Junta de Planificación. La Tabla 2 muestra el porciento del total de costos que representa el gasto en productos (suministrado por la industria del petróleo) para los 25 sectores más intensivos en energía (en este caso combustibles). Nótese que la propia industria de petróleo, la electricidad, minería, construcción y cemento son las industrias más intensivas en el uso del combustible, por lo tanto las más afectadas en caso de aumento en los precios del petróleo.

El cuadro nos indica que los costos totales de producción (uso de insumos intermedios más el pago a los factores primarios de producción - capital, mano de obra, etc.) para la economía de Puerto Rico fueron de alrededor de $12,071.1 millón, de los cuales $491.9 millones fueron gastados por las industrias en consumo intermedio de productos de petróleo. El consumidor final gastó $70.8 millones en productos derivados del petróleo. La cantidad demandada por los sectores industriales constituyó el 4.1 por ciento de los costos totales (insumos intermedios más valor añadido) y el 8.8 por ciento del total de gastos en insumo intermedios.

El porciento que constituye el gasto en insumos energéticos del total de gastos es una medida de cómo se afecta la capacidad productiva de la economía total, o de los sectores industriales, en respuesta a aumentos en los precios del petróleo. De acuerdo a un estudio reciente para la economía de los Estados Unidos y otras economías mundiales:

> "The percentage response of capacity output to a one percent change in the price of energy is just equal to the share of energy costs in total factor costs" (2)

Según los estudios citados la economía de los Estados Unidos perdió cerca de un 5% de su capacidad productiva debido a los aumentos en los precios del petróleo. Asumiendo que la producción total de Puerto Rico (igual al costo total) de 1972 se acercó al punto de máxima capacidad y asumiendo que el "share" de energía a costo total (combustible más electricidad - 4.1 por ciento combustible y 1.0 por ciento electricidad) es del 5 por ciento (según datos del cuadro de insumo-producto de 1972) podemos estimar en forma aproximada la pérdida en capacidad productiva de la economía de Puerto Rico. Según nuestros cálculos nuestra economía perdió capacidad productiva en alrededor de $603.5 millones. Aplicando la relación de empleo a producción para toda la economía (61.1 hombres por millón de dólares de producción) podemos obtener una idea de la pérdida de empleos. Esta fue de alrededor de 36,846 empleos. Nuestros cálculos están muy cerca de la cifra histórica de cambio en empleo de 1974 a 1975. Según la Junta de Planificación el empleo bajo de 775,000 en 1974 (año en que se aumentan los precios del petróleo) a 738,000 en 1975 (una disminución de 37,000 empleos).

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(2) Véase: J. M. Griffin y P.R. Gregory, "An Intercountry Translog Model of Energy Substitution Responses," American Economic Review (December 1976). También R. H. Rasche y John A. Taton, Op.Cit., page 5.

Siguiendo los cálculos antes citados el 15 por ciento de aumentos en los precios del petróleo reduciría la producción del año 1977[3] ($12,282.2 millones) en $92.12 millones lo que implicaría una pérdida de 5,543 empleos. Los datos antes señalados nos dan una idea de la magnitud del problema que tenemos por delante.

Si los precios del petróleo no disminuyen en el futuro inmediato la alternativa será buscar nuevas fuentes de energía que reduzcan los costos de producción de los distintos sectores industriales y del consumidor final. Como explicamos antes la reducción en costos aumentaría nuestra capacidad productiva y por ende el empleo de recursos humanos. Por ejemplo una reducción en precio del recurso energético que disminuya los costos de producción atribuibles al consumo de petróleo y sus derivados en solo un 30% significaría en términos monetarios unos $150.0 millones en forma directa para toda la economía. La industria de la construcción reduciría sus costos en $44.2 millones, la manufactura en $54.7 millones y lo que es aun más importante el costo de producir energía eléctrica se reduciría en más de $15 millones. No solo se reducirían los costos sino que la capacidad productiva de la economía aumentaría en cerca de un 5 por ciento de la reducción en precios. Si la reducción en costos implica una reducción en las importaciones de la misma magnitud el producto bruto de la isla aumentaría ya que habría un incremento favorable en el saldo de nuestra economía con el exterior (aumentaría a nuestro favor la diferencia entre exportaciones

(3) Ultimos datos disponibles

e importaciones). En otras palabras no solo habría aumento en la capacidad productiva y el empleo sino que habría substitución de importaciones ayudando así a nuestra balanza comercial. Solamente asumiendo que nuestra producción bruta total aumentara (sobre los niveles de 1978) en un 2 por ciento se generarían más de 20,000 empleos adicionales. Sin embargo con toda probabilidad el aumento en capacidad productiva debido a una baja en los costos energéticos incrementaría nuestra producción en un porcentaje mucho mayor. Por el lado de la demanda la disminución en la tasa de inflación incrementaría la demanda final por bienes y servicios y el ingreso real disponible de las familias. El aumento en la capacidad productiva, disminución en importaciones, aumento en ingreso personal y aumentos en la demanda final no hay la menor duda incrementaría los ingresos al erario público en una cantidad considerable. Solamente un aumento en la demanda final (doméstica ( ) de 5% incrementaría la producción de $15006.4 millones a $15,710.9 millones (sobre los niveles de 1978), el empleo en unos 36,000 y los ingresos netos al fondo general del gobierno en unos $74.0 millones. Si el descubrimiento de una nueva fuente energética reduce los costos y aumenta la demanda final en un 9 por ciento la producción aumentaría de $15,006.4 millones a $16,329.2 millones (a precios de 1972) lo cual incrementaría el empleo en unos 69,000 y el ingreso al erario público en aproximadamente unos $133.3 millones.

( ) La demanda final doméstica no incluye importaciones. El cómputo se hizo resolviendo el modelo de insumo-producto cuya ecuación es $X= (I-A)^{-1}F$ donde X=producción, $(I-A)^{-1}$ matriz inversa de Lentref y F-demanda final doméstica.

Estas cifras aproximadas le ofrecen una idea aproximada al señor legislador de la importancia que tiene el asignar algunos fondos para "Research & Development" en el campo energético que redunden en el descubrimiento de nuevas fuentes energéticas que abaraten los costos de producción y los precios de los bienes y servicios.