CEER–X-31

R & D PROGRAM NEEDS FOR ENERGY ALTERNATIVES IN PUERTO RICO

(June 1, 1979)

PRELIMINARY REPORT

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO — U.S. DEPARTMENT OF ENERGY

CEER–X-31

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IN
PUERTO RICO

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P R E L I M I N A R Y   R E P O R T

LIST OF TABLES

Number	Description (Abbreviated)	Page
1	Reserved	
2	Estimates of Puerto Rico's Energy Requirements	9
3A	Schedule of Proposed Scenarios Program Objectives	11
3B	Possible Million Barrels Oil saved with scenarios	11
4	Potential "Energy and Cost Reductions"	12
5	Possible CEER Revenues from Fuels Tax R and D Law	13
6	Total CEER Funds Requirements	15

CONTENTS

		Page
EXECUTIVE SUMMARY		1
I.	Introduction and Background	2
II.	The Present Situation at the Center	3
III.	Future Projections	5
	CEER Mission	5
	Competitive Funding Prospects	5
	Energy and Environment Alternatives Under Considerations	5
IV.	Funding Alternatives - The Basic Problem	16
	Legislative Appropriation	16
V.	Conclusions	17
VI.	Recommendations	17
APPENDICES		
A.	Office of Energy Energy Alternative Priorities	20
B.	Proposed Legislation	21
C.	CEER Transition Funding Level	26
D.	Examples of Possible Scenarios in Energy and Environment	27
E.	Long Range Forecast of Energy Needs in Puerto Rico	96

EXECUTIVE SUMMARY

The Center outlines it's proposal solution for the ominous problems of energy and environment which threaten the well being of the Puerto Rico community. In a national and international context selected alternative energy sources and concomitant environmental problems are elaborated. Necessary funding and possible sources are analyzed. The unique position of CEER in ability to exploit the advantages inherent in the Puerto Rico site are included.

The possibilities of exporting technology are presented. Relationships with 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.

The main recommendation is that appropriately redefined role in R & D be assigned to the Center and that necessary funds be provided toward the goal of reaching energy independence or partial energy independence for Puerto Rico.

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 energy policy established in the public document of the Office of Energy dated May 1979 indicates in Graphic III-1, page 46 (Appendix A this document) the priorities given to alternatives energy sources.

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

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

(2) To present the necessary budget estimates during the next decade on a year by year basis of the funds requirements for a vigorous research and development program to ward partial energy independence.

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

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

II. THE PRESENT SITUATION AT THE CENTER

The Center counts as its principal resources 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 million dollars of which about 2.2 millions represent base

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The Center is presently involved in energy and environmental research projects within the total level of funding indicated. Such efforts have provided the Center scientists and engineers with a deep insight and knowledge in the frontiers of energy alternative development. The research projects include (1) Biomass Programs, (2) Ocean Thermal Energy Conversion (OTEC), (3) Direct conversion of solar energy into electricity through the use of photovoltaics, (4) production of steam for industrial uses, (5) fuels synthesis through fermentation processes-methane and ethanol.

The funding and the level of effort is still too small for a meaningful address at the scale required for Puerto Rico energy needs. The main bulk of the funding, approximately 2.5 million dollars, are DOE assigned funds under a present contract which will expire October 1, 1981. Probabilities of contract extension beyond this date are uncertain at present. Even if the present contract is extended the level of funding will never be adequate for a meaningful address to the solution of Puerto Rico energy needs.

III. FUTURE PROJECTIONS

A. CEER Mission

The 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. Research to Secure Environmentally Acceptable Energy Alternatives

Vigorous efforts will be required to solve the special energy and environmental problems for Puerto Rico. CEER is already involved in programs having the appropriate orientation, but much 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. The Office of Energy in the Energy Policy public document dated May 1979 assigns priorities to these alternatives. See Appendix A.

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.

As an example, Figure 1 illustrates the production cost of electricity from a 450 MW coal fired power plant with Flue Gas Desulfurization (FGD) located at a site similar to Rincón, Puerto Rico under various assumptions, several of which are indicated in the graph. (Figure 1 was obtained from ongoing economic studies of energy alternatives being performed at CEER and to be published). The production cost indicated in mills/kw-hr is a levelized value for the life of the plant which has been taken us 35 years. The abscissa indicates the year in which the plant begin. operations. For comparative purposes Figure 2 illustrates the same curve for the production cost of electricity from a coal plant. The levelized (during plant lifetime of 35 years) production cost of electricity are indicated for one 40 MW OTEC plant starting up in 1985; one 450 MW direct fired with biomass power plant starting up in 1987, one 250 MW OTEC plant starting up in 1993; and one 250 MW photovoltaic power plant with full energy storage to run at full power during nights and 25% extra storage allowance for rainy or cloudy days. The details of the calculations of these single points are given in Appendix D.

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)

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(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	36.1	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)
		ELECTRIC (1)					
YEAR	OTEC	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	4.0
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) YEAR	(2) MILLION BARRELS CONSUMPTION with SCENARIOS	(3) 1.5c/10^6 BTU TAX 10^6	(4) %	(5) 2c/10^6 BTU TAX 10^6	(6) %	(7) 2.5c/10^6 BTU TAX 10^6	(8) %
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.

CEER is the only agent on the Island capable of an already involved in such work for Puerto Rico. CEER will not be able without assurances of base funding to continue this leadership role.

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	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.

IV. 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.

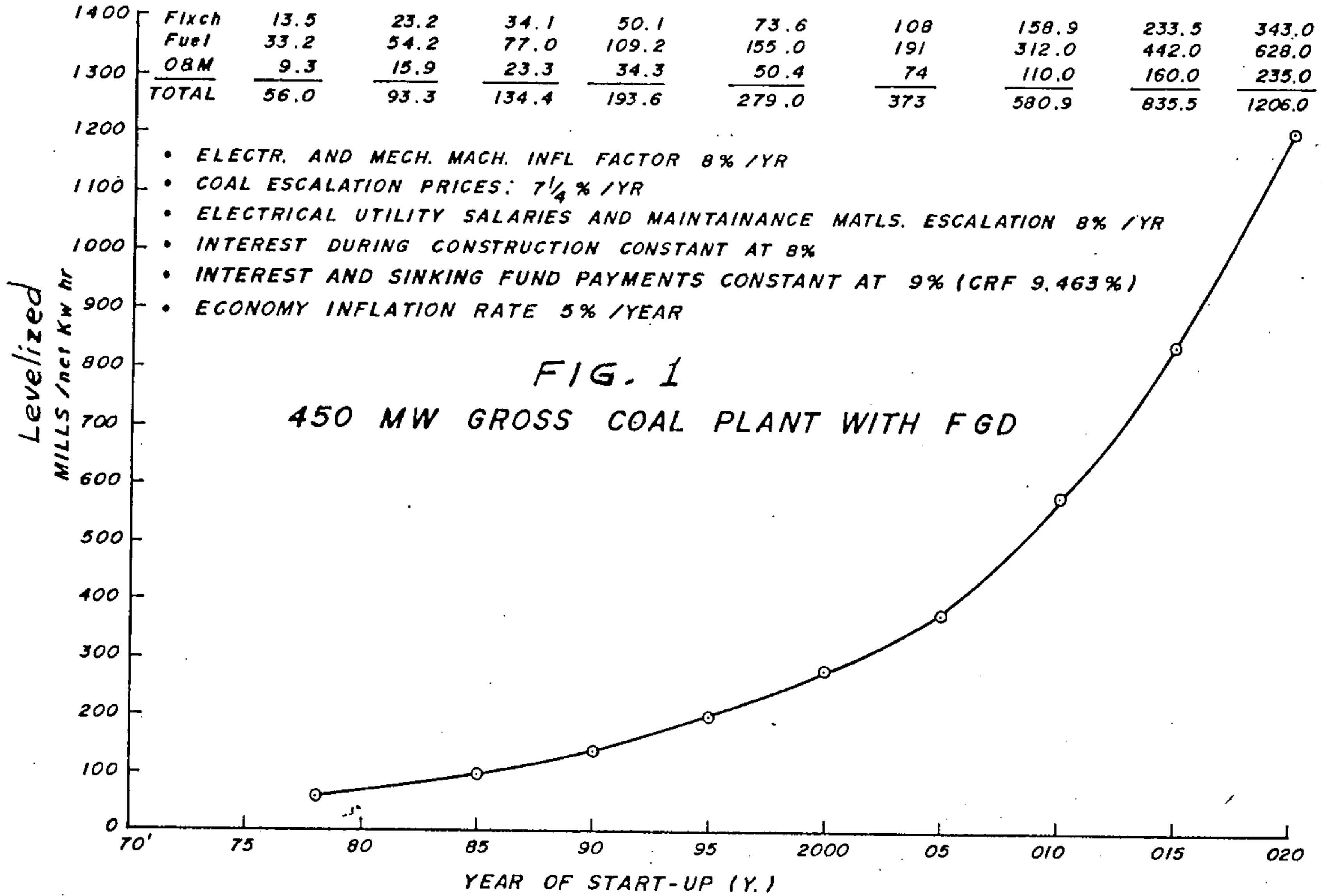
(e) The enactment of a new bill imposing a tax of 1.5-2.5 cents per million BTU on all imported fuels consumed or sold in Puerto Rico to finance CEER programs. Appendix B describes the proposed legislation. This is considered the most logical alternative.

V. 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.

VI. RECOMENDATIONS:

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



Fixch	13.5	23.2	34.1	50.1	73.6	108	158.9	233.5	343.0
Fuel	33.2	54.2	77.0	109.2	155.0	191	312.0	442.0	628.0
O&M	9.3	15.9	23.3	34.3	50.4	74	110.0	160.0	235.0
TOTAL	56.0	93.3	134.4	193.6	279.0	373	580.9	835.5	1206.0

- ELECTR. AND MECH. MACH. INFL FACTOR 8% /YR
- COAL ESCALATION PRICES: 7¼ % /YR
- ELECTRICAL UTILITY SALARIES AND MAINTAINANCE MATLS. ESCALATION 8% /YR
- INTEREST DURING CONSTRUCTION CONSTANT AT 8%
- INTEREST AND SINKING FUND PAYMENTS CONSTANT AT 9% (CRF 9.463%)
- ECONOMY INFLATION RATE 5% /YEAR

FIG. 1

450 MW GROSS COAL PLANT WITH FGD

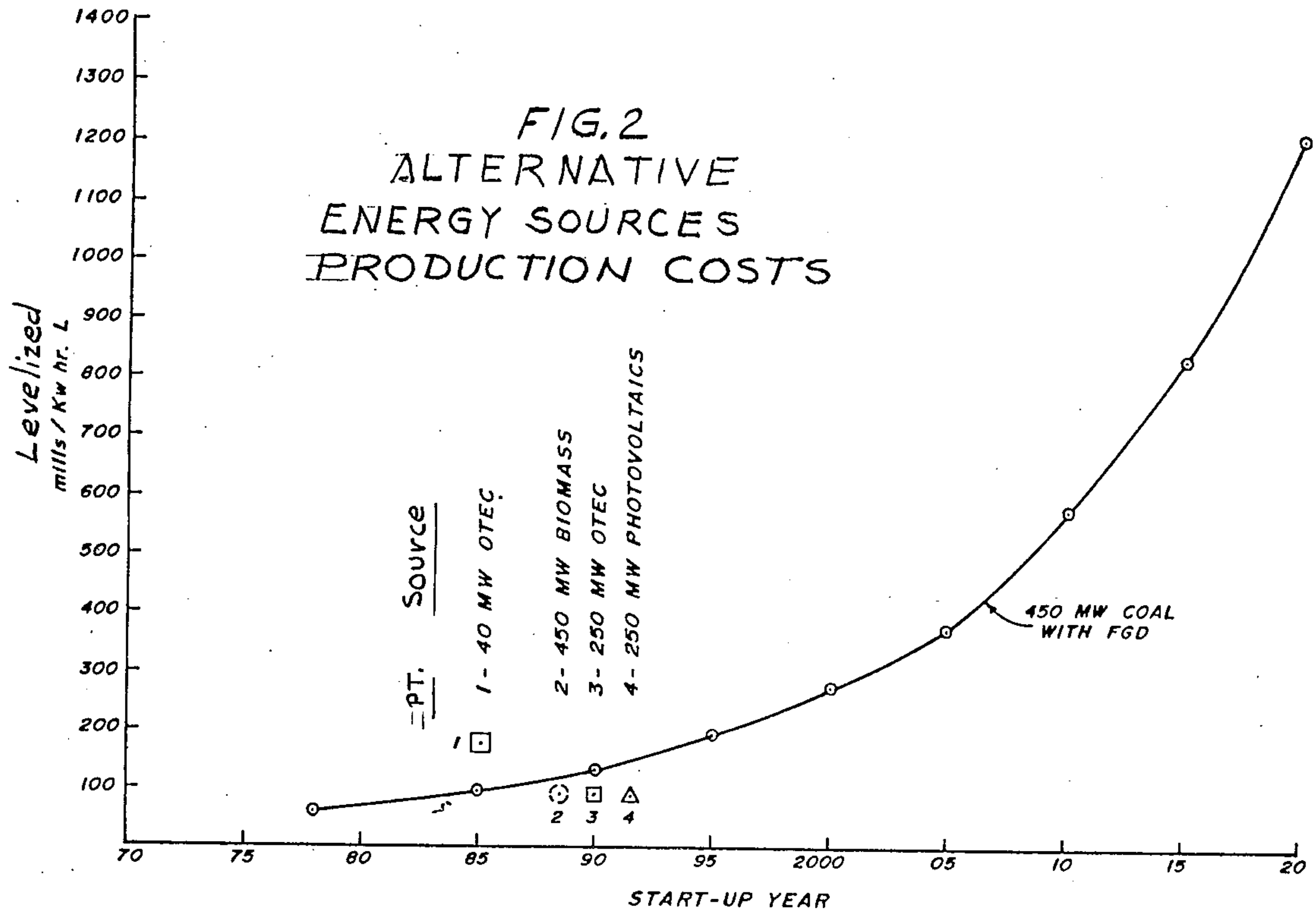


FIG. 2
ALTERNATIVE
ENERGY SOURCES
PRODUCTION COSTS

APPENDIX A

Términos Cronológicos para Determinar
Posibles Prioridades de Nuevas Fuentes Alternas

Período / Fuente	Corto plazo (de 3 a 8 años)	Mediano plazo (de 5 a 20 años)	Largo plazo (después del año 2000)
ELECTRICIDAD	- Desperdicios sólidos - Energía de viento -Calentadores solares de agua - Cogeneración	- OTEC - Bioconversión - Vapor por energía solar - Celdas solares fotovoltaicas - Acondicionadores solares de aire	- Concentradores solares - Celdas energéticas - Fusión
COMBUSTIBLE	- Biomasa - Combinación de alcohol y gasolina	- Alcoholes puros	-Hidrógeno

From "Política Energética de Puerto Rico" - May 1979

ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX B

PROPOSED LEGISLATION

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

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.

APPENDIX C

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

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

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
[illegible]	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	STEAM106BOi	BIOMASS	ETHANOL %ofgas.req.)	DIRECT SOLAR STEAM (OIL SAV.) MILLION BBL OIL ETHANOL PLT.	IND. STEAM
1979-84							
1985	1-40MW						
1986							
1987				450MW	11%	2.0	
1988						2.0	
1989				450MW	22%	4.0	2.0
1990	1-250MW					4.0	2.0
1991					33%	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	4.0
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
						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.	PHOTOVOLTAICS STEAM	BIOMASS	ETHANOL Gasohol	ETHANOL 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)
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 CONSUMPTION with SCENARIOS	1.5c/10^6 BTU TAX		2c/10^6 BTU TAX		2.5c/10^6 BTU TAX	
		$\$10^6$	%	$\$10^6$	%	$\$10^6$	%
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						
1985	89.37					12.92	.53
1986	87.76					13.41	.46
1987	85.96					13.16	.41
1988	85.53					12.89	.37
1989	85.40					12.83	.33
1990	80.13					12.81	.30
1991	86.13					12.02	.27
1992	91.43					12.92	.26
1993	90.30					13.71	.24
1994	92.83					13.55	.22
1995	89.96					13.92	.21
1996	88.89					13.49	.20
1997	88.82					13.32	.18
1998	88.95					13.32	.17
1999	88.58					13.34	.16
2000	95.58					13.29	.16
						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 PROJ[illegible]) 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.

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 photoelectric 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 it's 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

		Page No.
I.	OTEC	46
	A. Program Objectives	46
	B. OTEC Economics in P. R. Scenarios	46
	C. Approximate Cash Flow of Funds for a Demonstration Project	52
	D. Extrapolation to a larger OTEC Plant	52
	E. Risk Analysis Considerations	53
	F. Advanced OTEC Concepts	54
	G. OTEC Environmental Research Scenario	55
II.	PHOTOVOLTAICS	57
	A. Program Objectives	57
	B. Photovoltaics Economics in P. R. Scenarios	57
	C. Cogeneration Photovoltaic Project	63
	D. Advanced Photovoltaic Concept R & D	66
	E. Environmental Research Scenarios for Solar Photovoltaics	67
III.	BIOMASS	68
	A. Program Objectives	68
	B. Biomass Economics in P. R. Scenarios	69
	C. Energy Research Funds Requirements for Biomass	74
	D. Advanced Biomass Programs	75
	E. Environmental Research Scenarios for Biomass	75

CONTENTS

		Page No.
IV.	ETHANOL (MOTOR FUELS)	76
	A. Potential and Economic Implications	76
	B. Program Objectives	79
	C. R and D Funds Requirements	81
	D. Advance Concepts for Ethanol	82
	E. Environmental Research Scenarios for Ethanol	82
V.	SOLAR STEAM	83
	A. Potential and Economic Implications	83
	B. Program Objectives	84
	C. R and D Funds Requirements	85
	D. Advanced Concepts for Solar Steam	86
	E. Environmental Research Scenarios for Solar Steam	86
VI.	SUMMARY TABLE OF TOTAL CEER FUNDING REQUIREMENTS FOR EXAMPLE SCENARIOS	87
VII.	SUMMARY TABLES	
	Table 1 - Reserved	88
	Table 2 - Predictions of Puerto Rico Energy Requirements to the year 2000 under the same present socio-economic structures and under the absence of a strong R and D Program on Alternate Energy Sources.	89
	Table 3A- Schedule of Proposed Scenarios Program Objectives	90
	Table 3B- Possible Million of Barrels Oil Saved with Scenarios	90
	Table 4 - Potential "Energy and Cost Reductions" with Example Scenarios	91
	Table 5 - Possible CEER Revenues from Fuels tax R and D Law	92
	Table 6 - Total CEER funds Requirements for OTEC, Photovoltaics, Ethanol and Solar Steam R and D Programs	93

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

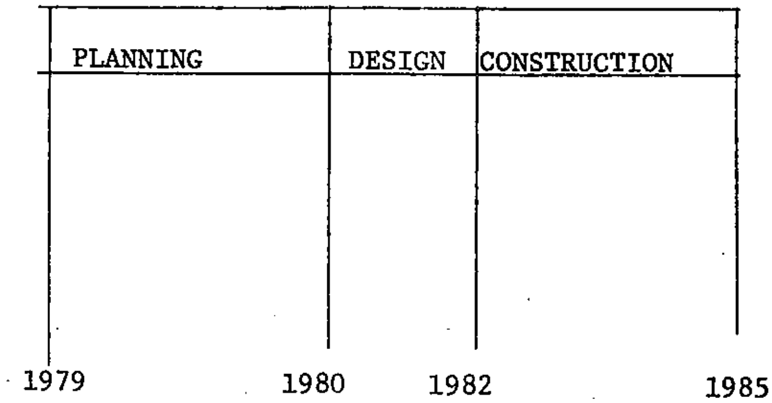
Demonstration Project-99.0 mills/kwhr

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

Figures 1 and 2 indicate the relative costs.

(*) 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 singel 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). Figures 1 and 2 indicate the production costs.

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

Year	P. R. Gov. Year	P. R. Gov. Cummulative	PRWRA Year	PRWRA Cummulative	DOE Year	DOE 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 1990 dollars (with 4 years construction time) = 39.5 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 1990 dollars will be:

$$(10.2)\ (2.25)\ (1.75) = 40.2 \text{ mills/kwhr}$$

Total cost is 80 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 Table 1.

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

TABLE 1

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 Toxicity of control treatment	Fouling influences efficiency, control methods cost Potential reduction in fisheries
2. Intake Design	Empingement potential Entrainment potential	Obstruction reduces efficiency Potential reduction of biotic stocks reduction of fisheries
3. Discharge Design	Field effects of different Configurations and operations Influence on currents Influence on elemental distribution Influence on temperature	Redistribution of plankton reorientation of fish Alteration of primary productivity-Food chain alterations leading to alterations in fisheries Bioaccummulation of heavy metals in food chains leading to man
4. Working Fluid Design	Field effects of leakage Acute Chronic	Direct human injury Direct kill of organisms 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

*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	10×10^6
		528×10^6

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

1993 Dollars Cost (5 years construction time)

Total escalation for Investment (1979-1993) = 2.33

Total Escalation Factor Salaries (1979-1993) = 2.76

Levelizing factor for Plant Life for Escalation of O & M = 1.75

Investment:	(26) (2.33)	60.6
Operation	(2.1) (2.76) (1.75)	10.1
		70.7

The cost of an equivalent coal plant is 148 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. Figures 1 and 2 indicate production costs.

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 3.15×10^9 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 and might properly be subcontracted to a qualified industrial/ environmental engineering firm.

It is difficult to estimate the costs of environmental research efforts required, but it will be assumed that such costs are included within the allocations indicated.

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. Large Scale Plant Project

Calculations for a 450 MW plant will be made in terms of 1987 dollars and will be compared with a similar coal fired unit.

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 for a coal plant 1985 dollars is 23.2 mills per kwh. Correction for 1987 gives 27 mills/kw. hr.

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 1987 dollar, 7 1/4 % escalation.

1987 Fuel Cost = $(1.70)(1.0725)^{8}$ MMBTU

Levelized (35 years) cost[1] = 1.75 (2.97)=\$5.20/MMBTU.

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

Levelized fuel cost is 52 mills/kw-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:

$P1 = P_s d = \$5.50/\text{ton}$

$S = .03$

$Tr = 200$ tons/hr.

$LF = 75\%$

$Y = 7$ years

$e = .08$

Substituting above figures in the formula gives, OM Desulfurization Plant = $\$5.2 \times 10^6$/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/kwh (1985 cost)

1987 cost = $12 \times (1.07)^2 = 13.7$ mills/kwh.

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(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.

dollars is:

Investment (same as coal plant)	27.0
Fuel	52.0
O&M	13.7
Total (Biomass fired plant cost)	92.7 mills/kwhr

The comparable cost for a coal plant is 120 mills/kwhr

If the 92.7 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. Figures 1 and 2 indicate production costs.

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

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(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 Bacardi Rum Distillery in Toa Baja (Palo Seco). This project is co-sponsored by Bacardi. The results of this project can be extrapolated to large industrial type of installation.

The proposed large scale ethanol facility in Section IV will require approximately 100 million pounds of steam per day. Assuming all steam requirements are produced by 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. <u>R&D Funds Requirements</u>

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		
1980	27.5	17.9	26.3	71.7	14.70	1001.
1981	29.0	18.5	27.7	75.2	16.78	1203
1982	29.7	19.0	29.1	77.8	19.17	1442
1983	31.9	19.8	30.5	82.2	21.30	1704
1984	33.6	20.5	32.0	86.1	25.00	2055
1985	35.3	21.0	33.6	89.9	28.55	2458
1986	36.7	21.4	35.3	93.4	32.70	2939
1987	37.9	21.9	37.1	96.9	36.29	3390
1988	42.2	22.5	38.9	103.6	40.28	3903
1989	44.8	23.1	40.9	108.8	44.72	4633
1990	47.4	23.6	42.9	113.9	49.60	5396
1991	50.8	24.0	45.1	119.9	55.00	6266
1992	53.4	24.5	47.3	125.2	58.75	7044
1993	56.0	25.1	49.7	130.8	62.75	7856
1994	59.1	25.7	52.2	137.0	67.00	9295
1995	62.0	26.0	54.8	142.8	71.50	9796
1996	65.0	26.4	57.5	148.9	76.50	10924
1997	68.1	26.7	60.4	155.2	81.12	12078
1998	71.5	27.4	63.4	162.3	86.00	13347
1999	74.1	27.9	66.6	168.6	91.15	14793
2000	77.6	28.1	69.9	175.6	96.62	16290
					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) ELECTRIC (1) PHOTOVOLTAICS 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) 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) YEAR	(2) CONSUMPTION MILLION BARRELS OIL: NO SCENARIOS	(3) CONSUMPTION MILLION BARRELS OIL: WITH EXAMPLE SCENARIOS	(4) REDUCTION 10^6 BBLS SAVINGS WITH SCENARIOS	(5) MILLION DOLLARS SAVINGS WITH SCENARIOS	(6) FRACTION (%) OF 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

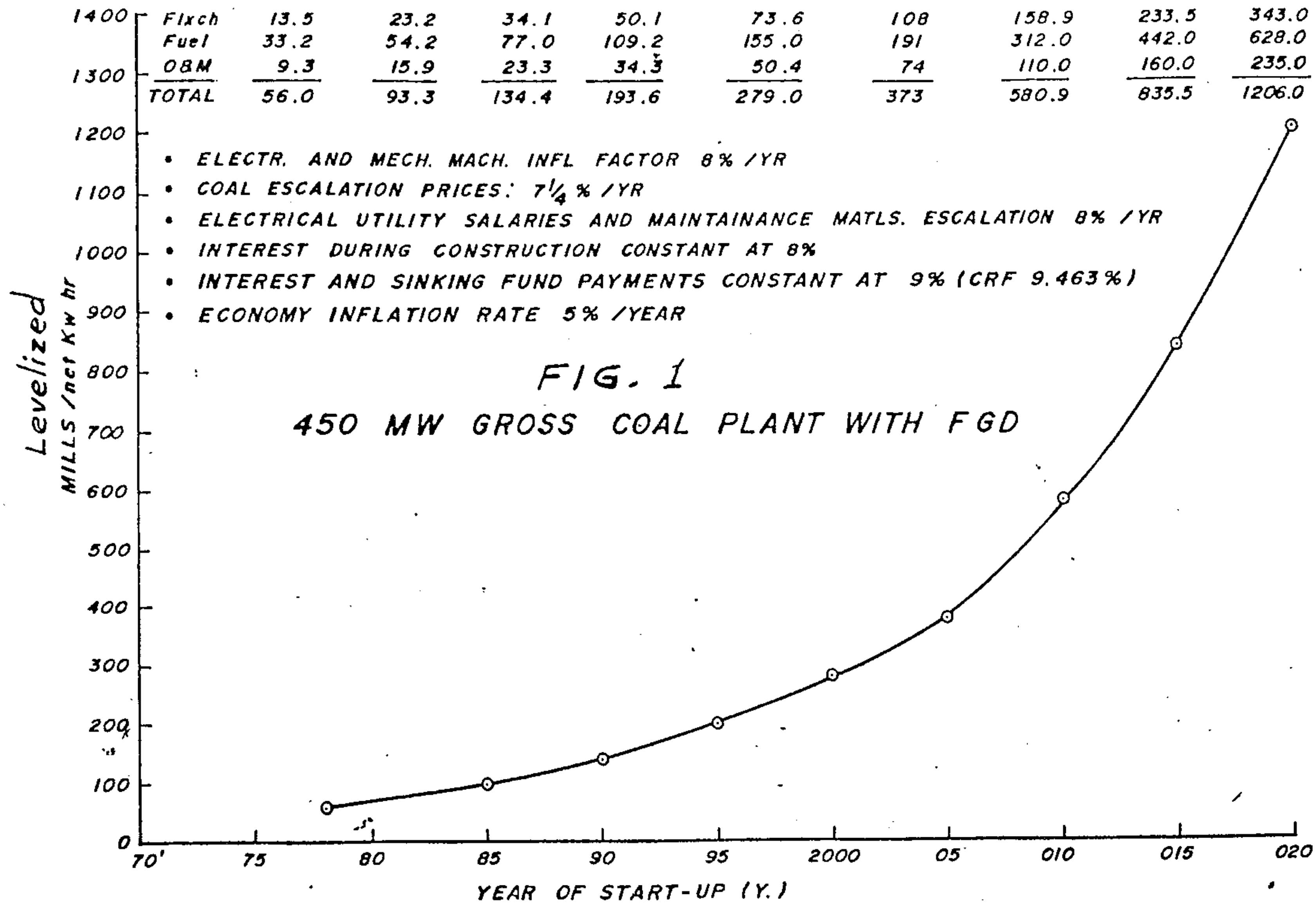
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
YEAR	MILLION BARRELS CONSUMPTION with SCENARIOS	1.5c/10^6 BTU TAX		2c/10^6 BTU TAX		2.5c/10^6 BTU TAX	
		$\$10^6$	%	$\$10^6$	%	$\$10^6$	%
1980	71.70	6.45	0.53				
1981	75.20	6.77	0.47				
1982	77.80			9.34	0.55		
1983	82.20			4.86	0.48		
1984	86.10					12.92	.53
1985	89.37					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 PROJ...) 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.



Fixch	13.5	23.2	34.1	50.1	73.6	108	158.9	233.5	343.0
Fuel	33.2	54.2	77.0	109.2	155.0	191	312.0	442.0	628.0
O&M	9.3	15.9	23.3	34.3	50.4	74	110.0	160.0	235.0
TOTAL	56.0	93.3	134.4	193.6	279.0	373	580.9	835.5	1206.0

FIG. 1
450 MW GROSS COAL PLANT WITH FGD

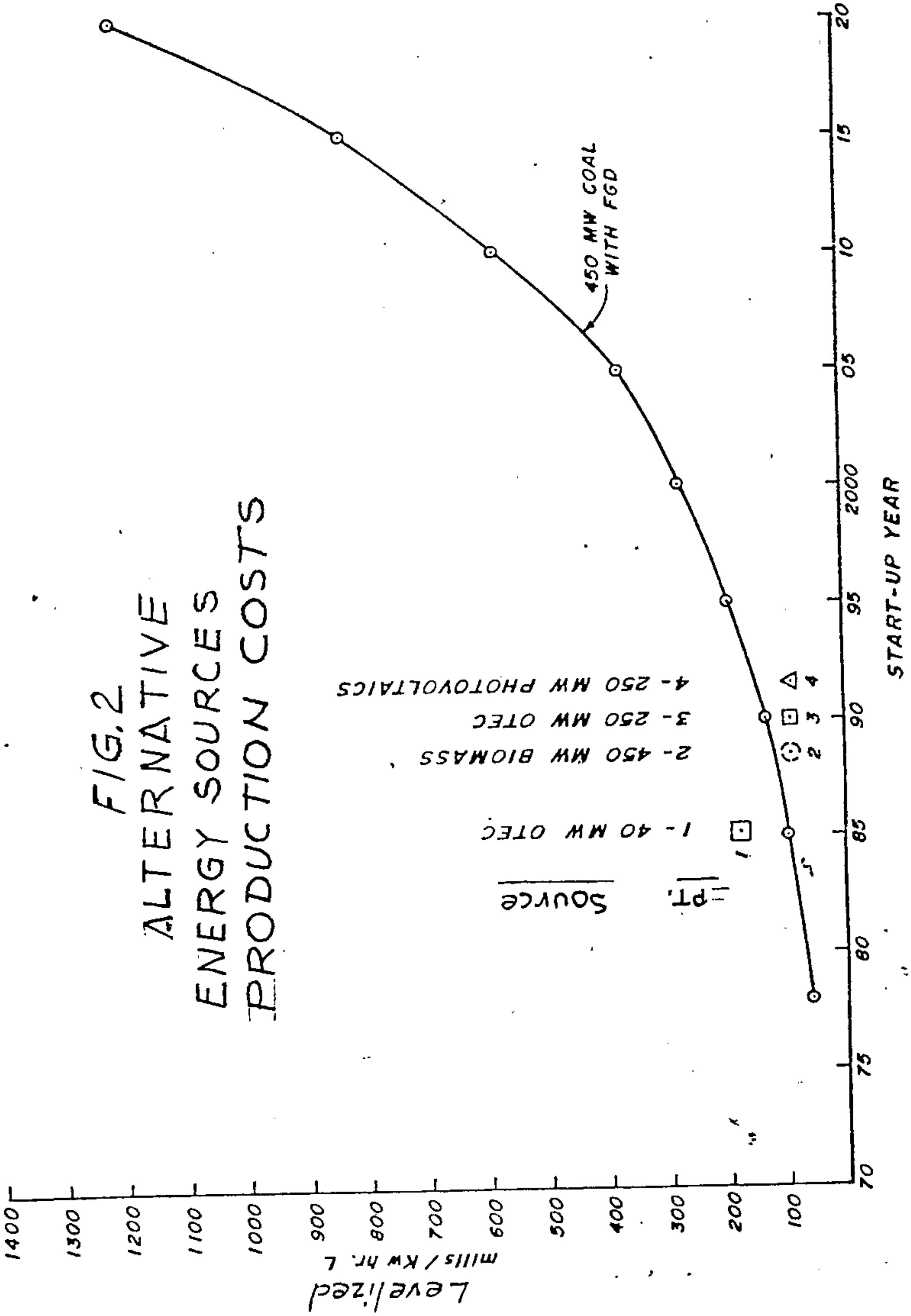


FIG. 2 ALTERNATIVE ENERGY SOURCES PRODUCTION COSTS

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

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- <u>Population</u>

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 incrementt 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 rèlationship 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.

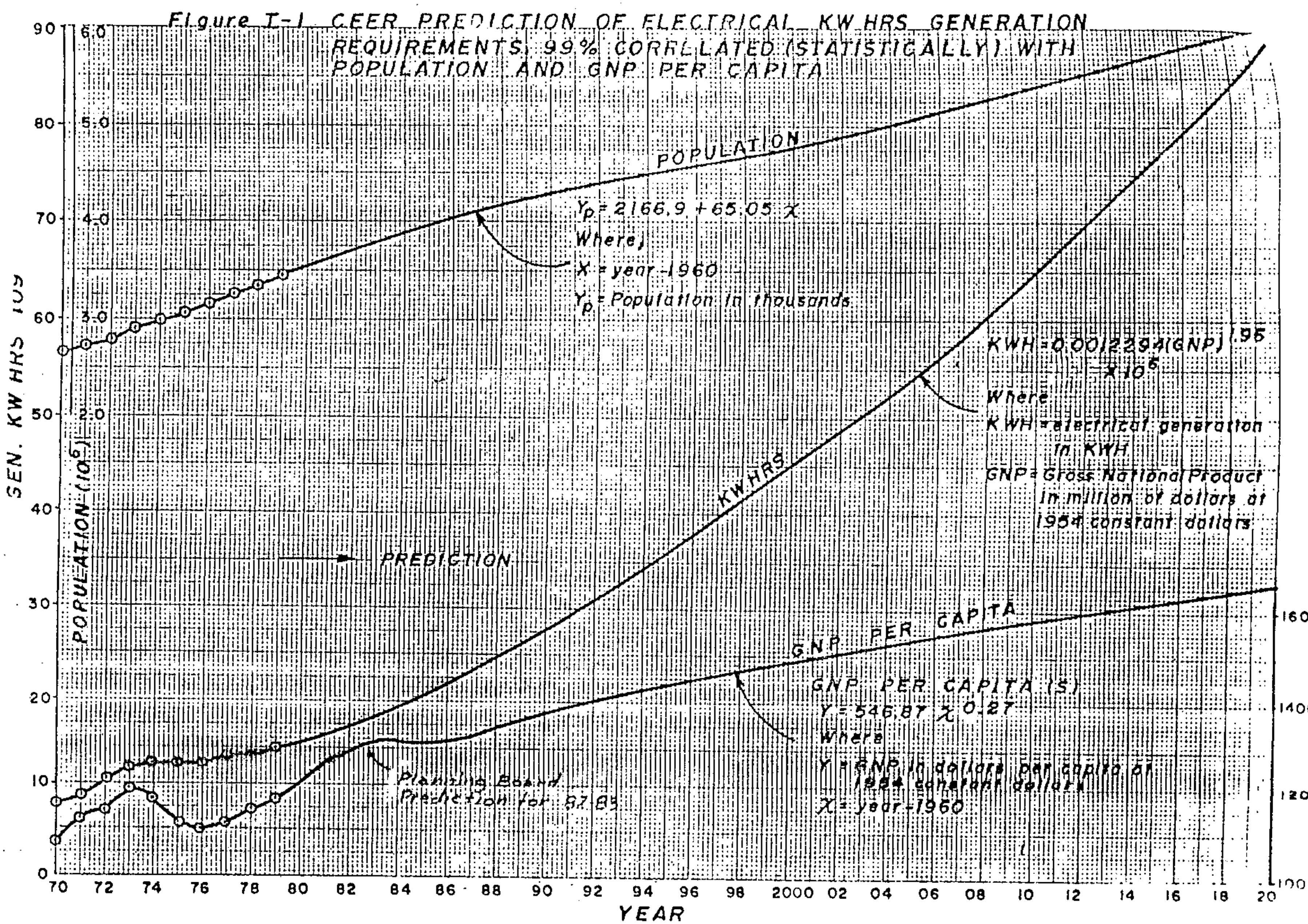

Figure I-1 CEER PREDICTION OF ELECTRICAL KW HRS GENERATION REQUIREMENTS 99% CORRELATED (STATISTICALLY) WITH POPULATION AND GNP PER CAPITA