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& D PROGRAM NEEDS FOR ENERGY ALTERNATIVES.

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PUERTO RICO

(June 1, 1979)

PRELIMINARY REPORT

& % CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

& UNIVERSITY OF PUERTO MICO ? US. DEPARTMENT OF ENERGY

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R & D PROGRAM NEEDS FOR ENERGY ALTERNATIVES,

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PUERTO RICO

(une 1, 1979)

PRELIMINARY REPORT

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LUST OF TABLES

Description (Abbreviated)

Reserved

Estinates of Puerto Rico's Energy

Requirements

Schedule of Proposed Scenarios Program

Objectives

Possible Million Barrels O{1 saved with

scenarios

Potential ?Energy and Cost Reduction:

Possible CEER Revenues from Fuels Tax

and D Law

Total CEER Funds Requirements

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contents

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EXECUTIVE swOARY

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 end international context selected alternative energy sources and concomitant environmental problene are ela~ porated. 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. Relation-

ships with U. 8, Department of Energy, the Commonwealth Energy Office

and the University of Puerto Rico are discu

fe conclusions are (1) Puerto Rico's energy crisis demands an

expanded role by CHER in R & D which previous levels of funding and

Snstitutional relationships cannot sustain. (2) vith adequate funding

CHER can convert the University of Puerto Rico into a technology export-

ing organization with special relevance to the Carib

mn, Latin Anerica

and other areas in the fields of OTEC, Biomass, Photovoltaics, ethanol

and solar steam, (3) the scale of operations and funding level of CEER Fe 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 pro~ portions.

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

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INTRODUCTION AND BACKGROUND

Reorganization in the Federal Government since the founding of

Puerto Rico Nuclear Center (PRNC) under the Atomic Energy Comission (ABC) in 1956 has resulted in the establishment of the Center for Grergy and Environment Research (CEER) with a new mission and found~

ing structure. The move in 1975 to start the proces

of making the Center self sustaining and competitive has necessitated the adoption of nov strategies for conducting research and finding new funding

sources. In these efforts CHER hi

been quite successful. An oxa-mination of progress toward self-sufficiency has revealed important implications for the long term success of the Center. In planning now for the future prograas 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 pres-
sing problens of energy and environment with which Puerto Rico and

the whole nation are confronted. The probless in Puerto Rico are
reat and vill require investment of resources which may have not

been considered possible five years ago.

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

?energy sources.

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of this document ar

In Line with this policy the objectiv

(Q) 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 prograns at the Center.

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

(3) To recomend a strategy for secking funding which are most appropriate for achieving partial energy independence as soon as practicable,

(@) To bring the attention on the necessity of providing self sustaining and continuous funding to the Center for Energy and Environment Research (CHER) to address the massive wrch and development programs required,

TL, THE_PRESENT SITUATION AT THE CENTER

?The Center counts as its principal resources fourty three scientists

?With an established reputation for productivity and respousiveness to

?the Department of Energy (DOE) needs especially in the areas of tropical

ecology, nuclear research, education and nore recently in alternative

?energy source development. The research facilities valued at §12 millions

fare the best in the Caribbean and the FY 1979 budget amounts to approxi~

mately 3.5 willion dollars of which about 2.2 millions represent base

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@Q) To present an

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appropriate for achieving partial energy independence as
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and Environment Research (CHER) to address the massive

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mately 3.5 million dollars of which about 2.2 millions represent base

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funding. Appendix C indicates the transition funding level of the Center. The Center has been nore successful than expected in securing funding from competitive sources during the first three years of the transition perfod (having secured $900,000, compared to a predicted $150,000 in FY 1978).

The Center is presently involved {n energy and environmental re search projects within the total level of funding indicated. Such efforts have provided the Center scientists and engineers with a deep insight and knovledge in the frontiers of energy alternative developnent. The research projects include (1) Biomass Programs, (2) Ocean Thermal Tergy Conversion (GTEC), (3) Direct conversion of solar energy into

electricity through the use of photovoltaics, (4) production of steam for industrial uses, (5) fools synthesis through fermentation processes ?methane and ethanol.

The funding and the level of effort ie still too snall for a mesning~ ful address at the scale required for Puerto Rico energy needs. The ?ain bulk of the funding, approxintely 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.

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FUTURE PROJECTIONS

GEER Mission

The mission of CBER is to address energy and environment questions that arise for che 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 developuent of the island. Orderly developeent requires the objective ascesonent of energy alternatives én the context of their environmental and economic costs. CEER

is the only institution on the Island with the appropriate

orientation, tradition, independence, reputation and exper-

tise to perform this necessary task.

Competitive Funding Prospects

While DOE funding of relevant research is expected to conti-

?ue it will become sualler fraction of the total progran needs. Hovever, it is unrealistic to expect that the observed vate 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 nore have to enter into competition with other established

Tesearch units for money from the United States and other

---Page Break---

sources. This will require an increasing expenditure of

effort on the part of CEEK staff. This is a coutiagency for

Which Little provision has been made in CEER struccure to date.

Using the national average for the rate of rejection of re

search proposals it nay be conservatively estimated that 1.3

rman years per year aust be spent in grant proposal preparation

to yield 1 million dollars of competitive funds.

Research to Secure Environmentally Acceptable Energy Alternatives

Vigorous efforts will be required to solve the special energy

?and environmental problens for Puerto Rico. CEER is already

involved in programs having the appropriate orientation, but

?much vork will be needed to solve the probles. Several cases

may be cited

examples of the relevance and cost effective

which have

ness of CEER's present and planned R & D progr:

relevance for the Comonvealth.

oT8C, photovoltaic, biomass, ethanol and solar steam are under

consideration ag 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 Mi plant generating about 1% of Puerto Rico's energy needs

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by 1985; @ 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 con
tribution to about 12% by the start of the 2ist. century.

Yor each of the energy alternatives assuaptions, costa and
environmental 8 & 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 tovard energy independence.

As an example, Figure 1 illustrates the production cost of

electricity from « 450 HM coal fixed power plant with Flue Gas
Pesulfurization (POD) located at a site similar to Rinefa, Puerto
Rico under various assumptions, several of which are indicated

4m the graph. (Figure 1 was obtained from ongoing economic studies
of eneray alternatives being performed at CEER and to be published).
The production cost indicated in mills/larhr is a levelized value

for the Life of the plant which has been taken us 35 years. ?The

abscis

indicates. the year in vhich the plant begin. operations.
For comparative purposes Figure 2 illustrates the sane curve for
the production cost of electricity froma coal plant. The leve.
Used (during plant Lifetine of 35 years) production cost of elec~
tricity are indicated for one 40 MW OTEC plant staiting up in
1985; one 450 MH direct fired with biomass pover plant starting

---Page Break---

up in 1987, ono 250 MW OTEC plant starting up i 1993; and one

250 Mil photovoltaic power plant with full energy storage to run

at full pover during nights and 25% extra storage allowance for

rainy or cloudy days, The details of the calculations of these

?single pointe are given in Appendix D.

The summary of the exauples scenarios considered, under crash type R & D Program heavily involving CER, is given in Tables 2t06.

Table 2 includes an

inate of the energy requirements in Puerto Rico for the period 1976 through 2000. It is assumed that the present socio-econonic structure persists and that a0 R&D Program in search of energy alternatives is functioning. The fuel DILL for Puerto Rico during the FY 1979 exceeds one billion dol ars and the totel bill for the rest of the century is estinated

at approximately 156 billion dollars. (2)

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2) Colum 6, Table 1.

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TABLE 2

ESTIMATES OF PUERTO RICO'S ENERGY REQUIRENTS TO THE YEAR 2000

[UNDER PRESENT SOCIO-ECONOMIC STRUCTURES AND ABSENCE OF

?STRONG RAND D PROGRAM ON ALTERNATE: ENERGY SOURCES

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TOT 3155,829,

(1) Statistical correlations between population and GXP and betwen GNP and Electrical mergy Coneration. Correlation 99%. ?see Appendix

(2) Gasoline Consumption grovth projected conservatively between 21/2 - 3% Ber year vs. 6.6% actual. More accurate predictions to be included in Cuan? Baerey Studies.

(3) Industrial needs projected at St per year grovth. More accurate predic~ fons to be included in CEER Energy Studies.

(4) Fuel oft proces escalation indicated is approximately 1980-85: 14.3%/years

1985-90: 11% year; 1990-95: 6,82/year and 1995-2000: 6X year,

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Table 3A presents an illustrative program of energy alternative

objectives under a very tight schedule which will only be achieved

by a concentrated and coordinated effort between the various

government energy planning related organizations and in which

GUER is the main R GD researcher, The contents of the table

are the anounts of power in electricity, steam, etc. which could

be achieved in the period indicated.

?Table 3B indicates the amount of ofl saved by the proposed

h progran by the indicated scenarios.

Table 4 itusteates the potential contribution of the

proposed energy alternatives scenarios to the total fuel oil consuaption 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 anount is probably the maxim saving vhich could be achieved since it is, predicated upon a very tight schedule and & & D crash prograns requiring interagency coordination and cooperation,

Table 5 illustrates a possible source of revenues to finance the R & D progres. A fuel tax for energy and environnent=

al research and development is proposed on all non-renewable

fuels consumption in Puerto Rico. The tax proposed is based on ?BTU consumption and it fluctuates between 1.5¢ to 2.5c per million BTU. A gallon of gasoline contains sone 140,000 BTU, therefore,

this would hardly add 0.2-0.35 conta to a gallon of gasoline.

A draft of such proposed legislation is included as Appendix B.

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SCHEDULE cr prOFOSED SCENARIOS rroceAN onsecTIVES

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TABLE 5

POSSIBLE CUER REVENUES PRON FUELS AX RED LAK

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Table 6 illustrates the total CHER funds requirenents for the

Glustrative scenarios. The last two columns of Table 6 indicate

the suggested source of funding.

Colum 13, labeled "Base Funding Requirements" in Table 6 i

the ainimun projected funding requirenents for CEER. If the proposed

exanple scenarios or any other similar type progran is not undertaken,

CEER still needs to be funded to the level shown in the indicated

dic

colum, This i jed more fully in the section below.

?An adequate attempt to solve the energy problens of Puerto Rico will require that during the period 1980 to 1990 a total of approxi-

mately §199 million(3) be made available.

This represents an average investuent in R & D for energy and enviroment 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.

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FUNDING ALTERNATIVE ~ THE BASIC PROBLEMS

Legislative Appropriation

Various alternatives of CEER funding vere investigated and discussed by the staff. They included:

(@) Extension of the DOE contract.

Good prospects exists for negotiating a new contract with DOE but it ie 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 dollere annually.

A very low probability of success was given to this alterne-

tive.

(©) 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 PRIRA to contribute with

revenues to the St

SE of ite gro: e General Fund. However,

recent amendments has committed fully this contribution in

relation with the fuel adjustment clause

nbsidy given to

consuners with less than 400 kuhrs monthly. The alternative

vas discarded,

(2) Request to the Legislature for fixed yearly allocations én the

level of $5-18 million (The Rum Pilot Plant legislative fund

allocations history was revieved). Due to the present tight

?overnment budgetary conditions a low probability of success

was assigned to this alternative.

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(©) The enactment of a now 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.

Vv, Concuusross

Puerto Rico's energy crisis denands an expanded role by CEER in R GD which previous levels of funding and institutional relation~ ships cannot sustain.

2. With adequate funding CHER can convert the University of Puerto Rico into a technology exporting organieation with special relevance to the Caribbean, Latin America, and other areas in the fields of OTHC, Bionass, Photovoltaics, Ethanol and Solar Steam.

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

4, No altemative institution of equal capacity for such a role is

perceived to exist in Puerto Rico,

5. Without adequate support for R & D the energy eriais wilt

Feach disastrous proportions.

VE. RECOMENDATIONS:

1, Te is recomended (1) that the appropriately redefined role in

RGD be assigned to the Center and that necessary funds be

Provided, (2) that proposed legislation on funding receive

adequate endorsement.

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[BNERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

APPENDIX

PROPOSED LEGISLATION

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

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APPENDIX 2

?A BILL FOR APPROPRIATING FUNDS FOR THE

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

STATEXENT OF MOTIVES

The Center for Bnergy and Environnent Research of the University of Puerto Rico is an institution dedicated to the study and develop-Rent 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 photovoltaic:

?ocean thermal energy conversion, use of sugar cane hybrids as biomass fuel, bilharsia control, effects of industrial developments and popu. lation growth on Land masses, ete.

The Center's principal objectives

1 o 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 environ

mental and related fields.

To continue research and training prograne in environmental

and technologies.

?The Center for Bnergy 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

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ion until the

operated by the University of Puerto Rico for the Coan

?agency was superseded by the U.S. Energy Research and Deve lopment

?Administration (BRDA) in 1975. The Nuclear Center trained sore than

2,000 students in nuclear sciences, engineering and medicine. Now the

Departnent 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 nore 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 rensinder of this century.

Puerto Rico, with its total dependence for energy on imported fossil

fuel, is perticularly vulnerable to dislocations in the global energy

market. This is an anonalous situation as there are few places in the

world s0 generously endoved with natural energy: solar radiation, ocean

temperature differential, wind, vaves, and currents, al1 potential non

Polluting pover sources. CHER has been doing some projects in this Fespect using the funds allocated first by the ERDA and now by the Departnent of Energy using the present available facilities which are capitalized at approxinately twelve million dollars ($12,000,000). These facilities are being transferred to the University of Puerto Rico by the Depertment of Energy (DOE).

CER has been operated by the U.P.R. under contract vith DOE in which the latter funds all the operational costs vhile 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.

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In September 30, 1981 che 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 vill aot

Tt is therefore, nce:

bbe enough 0 cover all the expens ry that

the Legislature appropriate the necessary funds to cover the CHER?

?operational needs in order to continue the development of new energy

Fesources which vill fulfill an urgent need for the people of Puerto

Rico.

For said purpose,

Be it enacted by the Legislature of Puerto Rico

le Te 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 environnentally 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 progeans already started should continue, and new projects and grants sought to perform research and development is already established, due to vhich it is necessazy that che Legislature

propriate the required funds to continue the sane.

3+ The sum to be appropriated every year are to be obtained

by levying taxes on all types of fuels, crude, refined or coubination

of both, that shall enter into the Commonwealth of Puerto Rico as herein specified.

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4- Taxes to be levied shall be equal to one and a half cents (30.015) per million BTU's (British Thermal Units) of calorific value wr (1980-81; 1981-82);

or its equivalent for the first two fiscal yi

two cents (50.020) 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 GEER starting July 1, 1981.

6~ ALL lavs or parts of lave in conflict herewith are hereby

repealed.

7 This Act shall take effect ninety (90) days after ies

approval.

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ENERGY AND ENVIRONMENTAL PROBLEMS IN PUERTO RICO

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APPENDIX D

EXAMPLES OF ALTERNATIVE SCENARIOS 18

[ENERGY AND ENVIRONMENT

(CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

UNIVERSITY OF PUERTO RICO

27.

---Page Break---

?THE ENERGY PROBLEN IN PUERTO RICO

Various efforts are being undertaken by a variety of organiza~ tions in the Puerto Rico Government in the pursuing of solutions co the energy and environnent problems which are adversely affecting Puerto Rico and its general economic welfare. Every effort tends to Provide sone degree of assistance to the solution of the energy Problem. Probably, as the Director of the Office of Enerny 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 prograns now under consideration.

The seriousness of the energy crisis is now looaing nore closely and threatening the Puertorrican livelihood, economics, health and every sector of the very 1ife and blood of the present

civilization as we know in the western world. It is, therefore, felt hat an outlook with an agressive energy program with definite goals and objectives should be developed and pursued to bring forth solutions in the shortest tind: possible but with known and calculated acceptable risks.

CER studies on the economy of Puerto Rico and the dynamics of population grovth predicts that in order to maintain nearly the sane 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 developnents which

---Page Break---

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

describes the

Model Used for the predictions. This Appendix is part of an energy study being perforned by CEER.

?The growth in electrical generation indicates chat the Fuerto Rico electrical system will need to add roughly twice the actual generation capacity before the year 2000 in order to keep just ?approximately the sane level of economic welfare. This statement, under the present serious prediction of increasing fossii fuel costs ?and scarcity of fuel oils is rather alarming. An agressive progran

to address the massive anounts of electrical energy generation

requixenents of Puerto Rico

's required as soon as possible.

?CEER PROPOSED PROGRAM

In order to positively address the energy situation CEER

Proposes, as an example, a strong R & D program on the following

alternatives:

Ethanol (Motor Fuels)

5+ Solar Stean

Specific objectives are set for each of these alternatives with

approximate start of operation dates and achedules of required R & D

funds.

---Page Break---

Bach alternative is evaluated econonfcatly in the Puceto Rico

sneray scenario, Fron the economic and technological potential and

the present state of developsent and the interest of the federal

Government, various approaches which might be acceptable by the

organizations concemed are developed.

?he summaries of the acenarioe considered, under a crash tyre
R 6D Progran heavily involving CHER, are shova in Tables ? 06.
Te following traces out the salient points of the overall proposal,
Appropriate detai2 is presented later in this Appendix.

Table 2 indicates an approxinate prediction of the energy
roquirenents in Fuerto Rico up to the year 2000. Under the present
socto-economic structure and without a strong R and D progeam 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 dollar

Table 3A presents the mentioned example Program of energy
altemative objectives under a very tight schedule, only achievable

Wy @ concentrated and coordinated effort between the various govern

ment energy planning related organizations and in which CEER is the
main R & D researcher.

Table 3B indicates the barrels of ofl saved by the proposed

rash progran example scenarios.

Table 4 illustrates the effect of the example encrgy alterna

?ves scenarios proposed in the total fuel ofl consumption of Puerto

Rico, A reduction of nearly 52,000. million dollars equivalent to

---Page Break---

TABLE 2

ESTIMATES OF PUERTO RICO'S EXERGY REQULIEMENTS To THE Yak 2000

UNDER PRESENT SOCIO-ECOWOIIC STRUCTURES AND ABSENCH. OF

'STKONG KANO D PHOCKAY ON ALTERNATE ENEKGY SOUKCES.

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995-1 ec 76.0 Seg 1 yane | 7-59] 58

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oer] ea 367 soit] ae 80 J

saa] 9S Ta 3a [ven | otis P9788

353] act a3 e626 | teste | secs [reso |

3000 [7 wet $5.9 [yysce lyons | hare

som $155,929

(9) statistical correlations between population and XP and between GRP and

Electrical Energy Generation? Correlation 998. See fopendin

(2) Gasotine Consuaption srovth projected conservatively between 2 1/2 3%

per year ve. 6.68 actual, Hore accurate predictions to be incloded in

EEN Enezpy Seastes.

(9) Tndusessad needs projected at Si yer year growth. Hore accurate predic~

tions to be included in CEER Enerty Stuciess

(® Fuet of1 proces escalation indicated ie approximately 1980-85: 14.3%/years

1985-90: ?LIE year; 1990-95: 6.82/year and 1995-2000: 6% year.

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TABLE &

POTENTIAL, ?ENERGY AND CoS? REDUCHYONE*

WERT EXANPLE- SCENARIOS

v oo. ? s 6).

RSTO. REDUCTION TaLLTOR FACT OF AT

TEELLION BARRELS OFZ 30° pas Dour [OP SCENARIOS

ivean [ro WITH ExwLE | ? SAVINOS ?SAVINGS ?SAVINGS OF

Scewanzos | scenarros | wim scewagros| wrmi SCENARIOS | TORAL-NON seswaRtOs|

1905 | 99.9. 29.37 o.s9 7.33 0.8.

1386 93.4 87.76 7oa-67 e

war [96:3 35.96 a0 ae

988 [703.6 ?|?ass3?] 208

1989 ?Tose 35:40} Tea.

1990113.) 20-13 7857

esr 9:5 26.15 1,984

fiso2 [48.2 ca 33.7 Bes

3993 | 130-8 | ??9 20 3050, Beri

3994 [137-0 [sa ast 3.156 ee

1995] 147-8 39.96. 32.68 aoa 378

3996] ?148-9 88-89 0:07 4,068. a0

1997155. aba 66.36, 3: 703 a3

1998|-t62-3 "es 95 73.35) 6 886 a7

3993] "1ea-6 | 86 3002 Ar a7

2000 | 175-6 95.58 180.02 3.210 a6

Jrorars| 2072.6 1415.62 57.38 5,909.0 368

lcosr

ts10® 145,066 |

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36x of the total dollar expenditures up to the year 2000 is accom

plished by the example scenarios. This high figure is probably the

maximum saving which could be achieved since it i

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 progran. 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 1.5e to 2.5e 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 requirenents for the

example scenarios. The last tvo columns of Table 6 indicate the

?suggested source of funding.

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TABLES

POSSIBLE CHER REVENUES PROM FUELS TAX RED LAW

o @ 8 © © © @

WELTON [156/70 Bre eT wae TSO amy

BARRELS aK. ?ax a

year | CoSUNPTTOT

with swe} 9 sr08] 4 si} 9

SCENARIOS

se0_| 71.70 6.45 | 0.53

1981 ?| 75:20. 6.77 [0-47

1962] 77:80 33a]

4983 | e270 26]

1964 | 66.10. Tae [Se

3985 | 69-57 13.40 [ae

7386 | 87.76 73:18 [ar

1967 | 65.96, 12-09 [37

7388 [85.53 1283

989 25-40 12:81 [30

1590 42:02 [27

1991 12-93 [236

1392. iar [ae

795, 33:35 [22

1994 73.92 [2

1995 13:48 [20

1996. 13.32 [16

3997 33.32 [7

1396. 1334 [16

7999) 1329 6

72000 1a [15

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The logic in selecting and setting the example scenarios has been based in the information, experience, and knowledge generated from R and D prograns 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 Departuent of Energy. This low level of effort needs to be incremented considerably as has beet indicated in ordér to produce memingftl results. Economic considerations and evaluations, potential capacity of the elternatives

to meet the local energy needs and actvsl technical status and

Projections of the alternatives were taken into considerations.

?These can be summarized as follows:

OTEC (Ocean Therma Energy Conversion) makes use

of the temperature differential between deep sea waters (3000 ft)

and surface vater to generate electricity.

This concept has the potential of generating all the enerey

Reeds of Puerto Rico at some future date. Ocean bs

oF Floating

type of plants in the southern Caribbeon sea vill have practically

no impact on land utilization resources.

Te ie estimated that an OTHC-10 (40 M4 plant) concept could

be operational within 4 years. Preliminary economic calculations

under certain assumption indicate PRVRA could afford §26.2 million

dollars tovard investaent and the energy obtainable vill be comparable

in cost to one 450 Mi 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

38.

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Project is estinated in $300 million including escalation and interest during construction. The Federal Government appropriation requirenent is $247.6 million. A risk analysis consideration indicates an accept able calculated risk for » public corporation.

Cost calculations were performed for 250 MY OTEC concept operational by the year 1990-1 and 4s chown to be 612 of the 450 *! coal plant cost of electricity. From this it 4s assumed that PRURA can then finance completely such concepts from there on.

Such an agressive approach will definitely win the OT8-10 concept for Puerto Rico over the Gulf States and Havaii coapetition

CER requested R & D funding are indicated.

PHOTOVOLIAICS - Photovoltaics systems produce electricity by converting direct solar radiation into electricity using photo electric cells. A large fraction of the energy is stored for use during non-daylight tine. It is a complete static aysten vith no know adverse environmental effects. The concept has enough potential fo generate all the electric energy needs of Puerto Rico required by

the year 2000 but it will require 90,000 - 100,000 acres of 1and ~

enormous farns of solar collectors cells and electronics.

?The objectives for photovoltaics systens are defined in the

Program, its economics in the Puerto Rico scenario assesed and the

RGD funds requirements are scheduled.

?The most aabitious objective in che 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

---Page Break---

fon a snall similar project being pliined 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 48t of the cost of a 450 Mi coal plant, without the steam cogene-

the economic attrac~

ration portion. When the steam portion is add

tiveness is even higher, These costs were determined for the P.R.

scenario by using higher costs than che most recent basic data cost information.

RED funds need to be secured by CEER from the Puerto Rico Govern-nent for this project in the level of $40 million excluding advance concept developments. It is assuned that the Federal Government will natch these funds for a total of $80 million requirements in RED. A consortium of private enterprises, PRWRA and Fomento is suggested for the capital investment.

qe

BIOWASS - Biomass is practically a1 agricultural enterpris
consists of planning selected optimized species for mass production,
harvesting, solar drying storage, transportation and burning the bio-
ass in a suitably designed boiler co produce stean to run the turbo
generators that produce the electricity. As such, an electric plant

fueled with bionass is not very different from a conventional fossil

fuel fired pover plant. Biontss alone can supply all the energy needs
fof Puerto Rico by the year 2000, but it will require 700,000-800,000
acres of land. One single 450 MH plant in operation by the year 1987,
operating at 752 capacity factor could supply 132 of the electrical
?energy needs. Approximately $5,000-60,000 acres of Land will be re-
quired to feed the plant.

Uy Solar Electricity and Wconoaie Approach to Solar Encrgy-Wolfgang
Alene ENC" RRRERIGUSERE "FOREN, Commission of European Communities

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?The principal and imediate objective in a biomass program will

be to convert an existing sugar mill co handle 1000 tons of biomass

per day and determine the logis:

eS, 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 Mi boil

?The econoaic analysis indicates that biomass is the costlier of

the three alternatives, but still has a good economical advantage

over @ coal alternative. The prelininary calculation indicated

that the cost of electricity trom bionass is 86% of the cost of

slectricity frome 450 Mi coal plant. Inite favor, is the fact that this

alternative will require the least expenditure of funds in R&D. , Techno-

logically it is the 1

risky of all three considered but is, of cour:

the most costly.

?The principal objective is to develop the neces:

ry data 50

that PRWRA can within 1-2 years incorporate, in its steam boiler bids specifications, enough data for specifying boilers to burn any of three fuels-oil, coal or bionass, and have all the logistics developed to burn biomass by the year 1986-87,

ETUANOL (MOTOR FUELS) ~ Ethanol can substitute gasoline oF can be blended with gasoline to form a mixture as gaschol. Gasoline vith 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

aaa

---Page Break---

rate of 6.62% per year during the last 12 years. The gasoline require-

ments of Puetto Rico for the year 1990 (assuning the grovth rate is

halved) is estinated conservatively in one billion gallons of gasoline (equivalents to 1.67 billion gallons of ethanol). This could be produced with @ program requiring 1,000,000 acres of sugarcane plantation which is approximately 89 % of the agricultural land in Puerto Rico. Cost are estinated to be competitive.

The R & D program objectives include the modification of « sugar ?sill 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 gaso-

Line requirenents by the year 1990. the indicated objectives are based on approval this year of planned pilot plant operations at the UPR-RIM Experimental Station and existing prograns of development of saccharum hybrid species for increased yields. Total R 6 D Funds requirenents 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 under~ vay with Bacardi Distillers to produce solar steam at the Bacardi Run Plant in Toa Baja (Palo Seco).

The production of ethanol as well as many other industrial processes, requires large anounts of steam. The production of Li of ?the gasoline requirenents for the year 1990 in ethanol will require

approximately 1 million pounds of steam per day.

---Page Break---

?The progran objective is to reduce the cost of ethanol (and the energy requirenents) by supplying at least 40% of the steam Fequirenents of the ethanol project previously described with solar enersy.

?This will further enhauee additional industrial uses of the technology.

Te is estimated that the K 6 D funding requirements for this

project is $25 million excluding the development of advance concepts

sind related material development.

Total Budget

The total R & D budget vhich will be required by CEER fro the

Puerto Rico Government to agressively attack all alternatives

is indicated in Table 6 entitled " Sumary Table of Total CEER

Funding Requirenents for Example Scenarios".

?The details and rationale of the proposed program are contained

in the eechnical analysis which follows.

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APPENDIX D

?TECHNICAL, ANALYSTS OF ALTERNATIVE ENERGY SCENARIOS

?conten

A. Program Objectives

B. OTEC Economics in P. R. Scenarios

©. Approximate Cash Flow of Funds for a

Denonstration Project

D. Extrapolation to a larger OTEC Plant

E, Risk Analysis Considerations

F.? Advanced OTEC Concepts

©. OTEC Environnental Research Scenario

11. PHoTOvoLtatcs

?AL Program Objectives

3. Photovoltaics Economics in P. R. Scenarios

C. Cogeneration Photovoltaic Project

D. Advanced Photovoltaic Concept R & D

B, Environmental Research Scenarios for Solar

Photovoltaics

MII. Bross

Program Objectives

B. Biomass Econonics in P. R. Scenarios

©. Bnergy Research Funds Requirenents for Biosase

D. Advanced Bion:

Prograns

E, Bavironnental Research Scenarios for Biouass

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ETHANOL, (MOTOR FUELS)

A, Potential and Economic Implications

B. Program Objectives

C. Rand D Funds Requirements

D. Advance Concepts for Ethanol

E. Environmental Research Scenarios for Ethanol

SOLAR STEAM

A, Potential and Economic Implications

B. Program Objectives

C. Rand D Funds Requirenents

D. Advanced Concepts for Solar Stean

E. Environmental Research Scenarios for Solar Steam

SUGARY TABLE OF TOTAL CEER FUNDING REQUIREENTS FOR

EXAMPLE SCENARIOS

SUMUARY TABLES

Table 1 ~ Reserved

Table 2 ~ Predictions of Puerto Rico Energy Requirenents

to the year 2000 under the same present socio?

economic structures and under the absence of

strong R and D Program on Alternate Energy

Sources

Table WA- Schedule of Proposed Scenarios Program

Objectives

?Table 58 Possible Million of Barrels Of1 Saved vith

Scenarios

Table 4 - Potential "Energy and Cost Reductions? with

Example Scenarios

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76

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AUALYSIS OF EXAMPLES OF POSSTBLE SCENARIOS IN ERGY AND ENVIRONMENT

1. ore

A. Program Objectives

1, Denonstration Plant in Operation by the year 1984-85,

4 40 Mi 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

POE Program). This plant could generate about 1.12

of Puerto Rico energy needs by 1985.

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

?4-250 Mii plant can be planned ag an extrapolation

of the Denonstration Plant.

The Demonstration Plant plus this plant can generate

7% of Puerto Rico energy needs by the year 1990.

3. Electrical System Addition on competitive Basis,

First 500 Mi OTEC Plant in operation by the year 1995

and addition] 500 Mv OTEC unite in the years 1977, 78,

and 79. ALL the OTEC units could be generating the

equivalent of 17.5% of the electrical energy requirenents

of the year 1999.

3, OTEC Economics in Puerto Rico Scenarios

?A 40 MW Deno Plant is estimated to cost about $5,000 per

?ee in 1978 dodtars,

The estimated cost of energy can be roughly figured as

follows:

---Page Break---

Investment charges

4, Project Investuent

(40,000) (5,000) ?) -. -$200,000,000

b. Yearly Investment charges

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

cc. Yearly energy production

298 x 108 kvbe

at 85% capacity factor

4, Investment charges in mills/

eve

~ 67-1 mille/kwhe

Operation and Maintenance (06M)

The O6M cost of an OTEC Plant cannot be too far off the costs of an equivalent ofl plant.

The marine portion, svch as hull and exposed sea water parts will require more maintenance, but these parts could probably be taken care of in a larger tine cycle than the routine yearly maintenance. This could probably be accom plished by moving the plant to special shipyard facilities.

?Assuming that the single OTEC plant will take the sane

amount of manpower as the two (450 Mi each) ofl fuel

Aguirre Units this would amount to approximately a staff

of 170 men. At an average salary of $24,000 per man,

(PHBA average salary for pover plants) the total staff

Deep Oil Technology, Inc. Subsidiary

Fluor Corporation. Unpublished. February 1979.

---Page Break---

Total Staff Salary

170 x 24,000 ?=-??????-???

$4,080,000

The ratio for a coal plant (which is a sore complex

operation) between total staff operation cost including

Flue Gas Desulfurization costs has been determined by

GEER Studies to be 2.33. Using the same ratic

Total 0 and ¥

(2.33) (4,080,000) =~. 9,506,000

06M costs in mills/

whe ??? 31.9

3. Fuel Costs

?The fuel costs are estinated to be 0.0 _

Total costs

Denonstration Project-99.0 mills/kwhr

1978 dollars

1985 Total levelized costs ?*)

This cost can be estinated by including escalation

and interest during construction and levelizing the O&M

jealation

cost during the plant 1ifetine. Assuming 7%

er year, one year period planning and contracting arran~

genents, 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, ete. see

ARERR TER REREE Sed MOBY HO SERSEL gy Sommer HALTY ava

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PLANING DESIGN

79 1980 1982 1985

Escalation before construction = (1.07)

Escalation during construction = (1.07)2:5

Interest during construction = (1.07) 15

Investment Escalation and Interest during

construction ~~ Total Factor = 1s

Operation Escalation at 7% /yegr between

1979 and 1985 ~??-?-??- (1.07)© = 1.5

Levelizing factor for 35 years lifetime

at 10% cost of money in a 5% infla-

tionary econosy yield a levelizing

factor of 1.75 @)

Total levelized cost 1985

Investment charges:

= 100.65

(67.1) (2.5)

Operation and naintenance

(31.9) (1,5) «1.75

40 si orbe Plant total levels 104.3 mitts,

Higures 1 and 2 indicate the relative cos!

(#) For Escalation and interest during construction considerations

fas well as levelizing considerations, cost of money, etc. see

arate CEER studies (Base line costé of comercially available

energy alternatives in P. R, scenarios).

a 49=

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Comparative Co

The above cost can be coupared with 92.5# nilis/kvhr

for a singel 450 i coal plant at Rincéa with flue gas

Desulfurization, 35 years 1ife and operating at 75%

capacity factor (the lover capacity factor is justified

in an economic dispatch competition). Figures 1 and 2

indicate the production cost

If the investment charge of the OTEC plant were 8.8

ills/kwhit the coal plant and the OTEC plant vill have the

?sane energy production costs of 92.5 mills/kwhr (total 1e~

velized cost during plant Life); at 8.8 mille/kwhr the

total yearly investaent charge will be $2.62 millions (85%
Plant capacity factor) which justifies an investuent of §26.2
millions in terms of 1985 dollare for PRARA (or $17.4 millions

in terms of 1978-79 dollars).

for the RSD and subtructure requirements for a total contri-
Dueion of $52.5 millions dollare (1985 dollars) from Puerto
Rico, the Federal Governnent contribution to be sought is
267.5 million dollars (1985 dollars).
The fund distribution under this schene could be:

* CBER Studies on Baseline Costs of Commercially Available Energy Alter
natives. The cost quoted needs revision for cooling water system
acceptable alternativ.

---Page Break---

?ION IN TERMS OF 1985 DOLLARS

RRA $26.2 millions ~ (plant investment)

PLR. Gov, 26.2 millions ~ (R&D)

Fed. Gov. 247.6 millions ~ (plant investment plus

7a)

$300.00 millions

Costs, mills pe

PRKRA OSM 83,7)

PRERA Investment.

Sub-total

P. R. Gov. Investment

Total P. R.

Federal Gov. 83.0

Total 184.3

The funds assigned by the Puecto Rico Government should

be mainly for R&D, substructure Facilities, laboratories, and

operational RéD.

?WD ?This should be the maximum fixed by contract.

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

Plant discussed.

---Page Break---

©, Approximate Cash Flow of Funds for Deno Project

PLR. Gov. PRURA DOE

tear | year cunmitative | Year cumaulative| year Cumut

79 ~ ~ ? _

180 2 2 102 16 sx} os

a1 3 2 10x 20 sx} 10

82 ast 4a 102 30 sx | as

83 16 38 oz 40 asz | 30

1 202 ? 20% 60 sox | 60

85, 22 300% 40% 100 4oz_| 100

Puerto Rico Government should be:

Tn terms of dollars the contribution to OTEC from the

Year | 1980] 1981] 1982 | T9as | 98a Toes

Tas

$ 3.1] 3.97) 3.93 | 4.09 | 5.24 | 5.86

Extrapolation to Larger OTEC Plant -(Objective #2)

TE the results of the Deno Project are satisfactory an ex=

trapolation to build @ 250 Mil plant can be sade with « high

degree of accuracy. PRWRA can share a higher risk and the Govern

rent also.

Te is expccted that auch plant would cost $1500/kw in terns

of 1978 doliars.

=52-

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The cost, of such 2 plant would be:

Investment charges:

2300)" (21)

20.1 nits

8760) C5), Ook wid

and in term of 1990 dollars (with 4

= 39.5 mills *

06M costs will be

douisre.)

?s construction tine)

ssuned to be twice the staff cost (1978

(9,506,000) x 2

TSU, DOO FEY 8S

The levelized 1990 dolla:

(20.2) (2.25) (2,75) = 40.2 milis/ieine

Total cost is 80 mills/kwhr.

Tis i

is much lover than @ fossil plant. PRWRA can finance

it completely.

B, Risk Analysis Considerations (of Denonstration Plant of

Objective No. 1)

Since PRWRA is a public corporation, it has to operate under

?sound economic policies in order to market ite investment

Yonds in the open bond market. It cannot invest in any ven~

ture without taking a calculated risk. The percentage of

investment funds assigned to PRYRA in the preliminary econo

nic analysis presents

here is 8.733% of the total funds.

+ Feasibility Design Studies ~ Deep Oil Technology Inc.Subsidiery

Fluor Corp. Unpublished. February 1979.

---Page Break---

If we correlate as a zero order approximation the risks of
4 project success to the investment by the private sector on a
one correlation between risk and investment, then we can assune
that Gf the chances of success of OTEC are better than 8.733/100
?the PRIRA 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 sane
risk as PRIRA, 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 ge~
eral 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 OT8¢ Concepts

After the first OTEC plants become operational R&D funds

need to be secured for improvement of the existing cubryonic

technology and technical problems which might arise.

?The foam ORC concept under investigation by CEER should

sigoment

receive more detailed consideration then. A yearly

---Page Break---

of $1.0 million dollars (1979 ba:

) should be allocated for

these purposes from 1986 on. At 8% escalation beginaing in

1979, the following escalated allocations are computed,

ADVANCE OTEC CONCEPT FUNDING (SUTLLTONS)_

2986 1987 19883989 1990

©. OTEC Environmental Research Scenario

?The primary environmental issues

sociated with OTEC appear

to be associated with:

1. heat exchanger design

intake design

discharge design

4, working fluid design

general unit configuration

AIL the above impact upon the process of site selection. A schematic of the interrelation between the technology development, the development of needed environmental inforsation and econoaic/ aesthetic considerations is presented as Table 1.

Te Gs assuned that the funds for environmental research are included within the allocations already mentioned.

---Page Break---

TABLE 1

OTEC ENVIRONMENTAL PROJECT

CFEC ENVIRONMENTAL ECONOMIC] ?AESTHETIC

TECHNOLOGY INFORMATION ?CONSIDERATIONS

DEVELOPMENT NEEDED

Heat Exchanger

Design

Biofouling Potential

of different configu-

rations, 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 ele-

mental distribution

Influence on tempe-

ture

Redistribution of

plankton reorientation

of fish

Alteration of primary

productivity-Food chain

Alterations leading to

alterations in fisheries

Bioaccunmulation 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 comau-

nities, losses of economic|

species, losses of

aesthetically important

FORMS - impact on tourisn|

=56-

---Page Break---

TI, Photovoltaics

AL Progran Objectives

Spall scale demonstration (162 KW) project to be located

at CEER.

This small project will provide know-how to deal

with this nev technology and vill develop greatly needed

hhunan resources to tackle larger projects.

Project operational by mid 1980. Data gathering there-

after.

2, Blectric Power Installation in the higher insolation

areas of Southwestern Puerto Rico to provide 250 Mi

Photovoltaic installatio by the year 1993 and an ad~

dition of 250 MW photovoltaic plant capacity by the year

1993.

3. A cogeneration project to develop power and stean in an

industrial park with the photovoltaic plants.

Photovoltaic Economics in P. R. Scenario

1, Storage Criteria for P. R.

Te is assumed that 1/3 of the energy output of the

Photovoltaics during daylight time (8 hrs) will be deli-

vered directly to the load and 2/3 of the energy gene-

rated during the same daylight time period will be stored

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

---Page Break---

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 bre. The charging rate ca-

pacity of the storage system will be, on an aver

basis, twice its delivery rate. This provides an encr~ gency ?spinning? reserve of three times the continuous rate capacity of the photovoltaic installation for the electric utility, since the storage system can be dis

charged at the same rate as its charging rate. Credit

for the extra

inning? reserve capacity can be credited

at the rate of capital cost of a conventional gas turbine.

To take caro of absence of solar radiation during
rainy days and overcast skies and storage system mainte
nance problens @ 25% additional energy storage vill be
provided.

At an efficiency of collection and production of 4.5%

and aver

ye insolation pover of 7 KW-hr. per square meter
Per day, the required area for producing 1 KW of conti-
rnuous power is:

3x = 76.2 a

-38-

---Page Break---

The

wverage insolation power per square meter is

1/24 or .292 bw per sq. m. per 24 hour day.

2, nvestuent costs

?The cost of @ photovoltaic installation can be

approximated by the following relationship:

Plant corte _§ = array cost /a2

7 waren Gah ear

+ Power Conditioning Cost ($) + Storage Cost ($)

co iw

The following value are assumed from the present

lay technology and extrapolation of the sane.

1977 dollars

(1) Total array efficiency = 4.5%

(2) Array cose

Solarceli cost?) a)

1.0 mi11/em2 or $10.00/n?

Wiring, structure,

installation cost/a? §10.00°2)

Total array cost: $20.00/a2

(3) Storage cost

per kesh $25,

(4) Power conditioning cost per kwh: $50

Plant Cost:

20 4 (1.25)(25) (16) + 50

(045) (.292)

= 1522 + 500 + 50 = $2072/kw

?A §200/kw could be credited due to twice available

(2) Sane as coat predicted by Unesco.

G) Costs of $20.00 per kw-hr predicted by Unesco. Solar electricity and

economic approach to solar energy-wolfgann paiz enersy development. prosran

Goan iSn "BP Boropean Communiticx Brussels.? UNESCO 1978

=59-

---Page Break---

3. Land and land rights charges:

?The area for the plant (at a rate of 76.2 a? per

KW is 4760 acres of land. An area of 5000 acres will

bbe assumed at $2000 per acre the land cost is $10,000, 000

Total Plant Co:

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

Land: 5,000 acreas a 2000 _ 10 x 108

328 x 107

Investment charges in wills/kw-hr,

The scheduled and forced outage rate for photovel-
tales must be lover than for an OTEC plant, for which
sn 85% capacity factor has been assuned. 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 dolla

Investments charges in wille/lew bh.

= 28) G08

+ .06

(8760) (250,000) (.94)

26 mille per lw-hr.

5. 08M Costs

OGM costs will be figured on the basis of an

---Page Break---

Plant staff. The area per XW of plant power is 76.2 22,

therefore for a 250 MY module an area 4760 acres ie re~

quired. Such large farm electronics, wiring, ete. will undoubtedly require sone personnel. The folloving is, assuned:

1 Superintendent

2 Asse.

Superintendent

2 Secretaries

5 shife Supervisors

10 Shite operators

2 Electrical Engineers

4 Electricians

2 Blectronic Engineers

4 Blectronic Technicians

1 Instrument Engineer

4 Ynstrunent Technicians

1 Mechanical Engineer

3 Mechanics

2 Clerks

2 Janitors

5 Gardeners and general Landscapers

20 Security men (4 guarde/shifte)

5 Shift chauffere

61-

---Page Break---

1. Chauffer (regular hours)

3 Ueitity mon (general)

2 Chemical Engincers (storage system)

8 Assistant Chemist (storage systen)

1. Warehouse (epare parts) supervisor

2 warehouse clerke

1 Accountant

1 Purchaser, estimator

1 clerk

93 Total

Ave. salary per man §24,000

Total salar:

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

Assuning a factor of 1.0 for material replacement,

* ete., (and we believe thi

to be a very highly conser

vative assunption since photovoltaics is a static system).

Year Total OM $4, 464,000

mills/kw = 4,464,000 = 2.1 witis/kwh

(250,000) (8760) (.94)

Total costs:

Tavestment 25.00

0 and 2210

Total (1978 dollars) 27.1 mills/kwh

62-

---Page Break---

1993 Dollars Cost (5 years construction time)

Total escalation for Iavestment (1979-1993) = 2.33

?Total Escalation Factor Salaries (19791993) = 2.76

Levelizing factor for Plant Life for Escelation of

Ogu = 1,75

Investment: (26) (2.33) 60.6

Operation (2.1) (2.76) (1.75) 0.2

70-7

The cost of an equivalent coal plant is 148 afite/keh (450 "61 coal plant). The photovoltaic concept cost of energy ie 48% of the cost of a 450 ty coal plant.

The project should be suitable for comercial financing. ?Te cost of the plant itself, eatinated at $2072/kw can be ?rice or higher in cost and still the plant will be compe titive with coal. Figures 1 and 2 indicate production cost:

Gogeneration Photovoltaic Project

1, The economics of photovoltaics looks very promising in

the P. R, Scenario, Since a photovoltaic installation takes

4 very large area a power plant site needs special conside~

ration, An industrial park can very well be developed adja~
cent to the photovoltaic plant where process stean is produced
during the daylight hours from waste heat of the solar col~
ectors and backed up with of1 fired boilers or biomass fired
boilers during the night houre. Such a system will offer

---Page Break---

great economical incentives to industry. The magnitude of
this project will require detailed research vhich is being
Performed at CEER on photovoltaics and waste heat collection.

2. Photovoltaic Cogeneration project cost

sstinate,

4. 250 MW Power Plant Cost $467 millions

b. Cogeneration Cost Estinate (for evaluating level

of RSD funds requirenent only).

?#oout 4 KW thermal pover is produced for every 1.00 KE
Produced in the CEER 150 KWS cogeneration project under
consideration. A steam flow of 2,122 1bs/hr. at 220°F with
aa enthalpy of 765 BIU/# is predicted together with
?en output of 151 ke, There is no condensate return in the

CER 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 extrac
ted is approximately 900 Btu/Ib of steam. This is equivalent
0 12,600 Beu/he, of thermal heat delivered per kw-hr. of
electrical power generation.

The total anount of heat that can be delivered in @
large co-generation project of 250,000 KW will be 3,15x109

Beu/hr, (Note that the 250,000 KW is the ave. 24 hr. daily

Beneration. The plant peak power capacity is three tines

~64~

---Page Break---

higher and it stores all the 24 hr. energy in the assumed

8 hrs. of daylight).

At 60% capacity factor of the steam portion, yearly ge~

neration in thermal heat is 2.2 x 1013 Beu/year. Figuring

conservatively $2.00 per MUBtu steam cost for @ competitive

project total gross yearly revenues are $44 million dollars.

The coger

ration project level of investment will there~

fore be in the order of 800-900 million dollars.

Yor any such project the RED funds are figured at 6%.

A level of $50 million dollars will be required for the RéD
of such a project. Since the project is predicated under
an economical basis, electricity being nearly half the cost
?of @ coal plant, and steas cost such lover than from oil
fired plant, the project can be funded by finantial enter-
prises on a commercial venture with FRARA, Fonento

and the PR, Government. The project could be in operation
by 1991-1992.

Te Ss assumed that the P, R. Governsent can contribute with
50% of R&D Funds and the Federal Governnent with the renaining
soz,

P. R, Government assignnent to this project is at « level

of $25 millions (1979 basis).

---Page Break---

The funding distribution is estimated

Research Punds for Photovoltaic Cogeneration $106

xe

follows:

Escalation Actual

1979 - _ s10®

1980 +50 1.08 56

1981 +70 Lay 81

982 1.00 1.26 1.26

1983 2.00 13600 *

1986 4.00 1.59

1985 5.00 un

1986 5.00 1.85 7.40

1987 4.00 2.00 4.00

1988 2.16 1.62

1989 2.33 =_

40.73

. Advanced Photovoltaics Concepts R&D

R&D funds for advanced concepts and material research

9 well as improvenent of existing operations facilities

should be allocated at least at the level of one million

dollars yearly (1979 basis) beginning in 1987. When eace-

lation is figured at 8% per year from the base year 1979,

---Page Break---

the following is the net result:

ADVANCED PHOTOVOLTAYCS CONCEPT FUNDING ($ Mii1ions)

1987 1988 989 1990

1.85 2.0 2.16 2.33

Environmental Research Scenarioesfor 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.

Te first question requires research by resource econonists

fand ecologists on the alternate uses of the land including

?evaluation of the possible destruction of rare and endan-

gered life forms, The second research effort is primarily

of the nature of an Environmental Inpact Statement and

night properly be subcontracted to qualified industrial/

?environmental engineering firm,

It is difficult to estimate the costs of eavironmental

Fesearch efforts required, but it will be assuned that

such costs are included within the allocations indicated,

---Page Break---

mn.

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

Design, construction, and operation of a pilot boiler plant with a capacity of 1000 tons of biouass fuel per day achievable by modification of an existing sugar mill, Project can be operational within 12 months after initial authorization, including the collabors tion of the PR Department of Agriculture and the

Sugar Corporation. Boiler size is comparable with 62,500 kw electrical pover plant boiler and is consi~ dered large enough for a seven-fold extrapolation to ?an acceptable 450 Mi boiler plant.

RRA shall be ready to request bids for 500 Mi steam

boilers suitable for burning any of three fuels (coal,

of, oF biomass) by 1981 or 1982, and have an operation

ral plant ready for 1987 or 1988, Additional unit

could be operating in 1989, A 500 ¥ plant operating

?at a 75% load factor will supply 10.7% of the enersy

needs by 1990.

Routine considerations to be given by PRNRA, under

available technological know-how and market conditions,

for evaluation of biomass on a competitive basis with

other available alternatives for future electric system

2

---Page Break---

3B, Bionase Economics in

A

additions beyond year 1990,

Scenarios

Pilot Boiler Plant: Te is estimated that a two-year project denonstrating a 1000 tons per day pilot boi Jer plant, operational on a 12-months basis, will

cost approximately $2.5 million in sugar-mill modifi- cation and logistics considerations plus $400,000 for fone year operation and data gathering. About 1/3 of

the investment will be in the biona:

production phase,
with special reference to off-season biomsss production during a 4-month interval when bagasse will not be available, To produce this fuel the project will re quire 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 irri~

gation systens with puxp and diesel engine installations ($380,000), and purchase of bionase 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

---Page Break---

charges for years 3, 4, and 5 will total §2.05 million. This project will provide industrial-scale data incident tot

a. Biomass production

b. Logi

ice of bionass harvesting, drying, storage,

transportation, and incineration

c. Logistics and costs of bionass-delivery technology

4. 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 comercial project identified under pro~

gran objective No. 2.

Large Scale Plant Project

Calculations for a 450 Mi plant will be made in

terns of 1987 dollars and will be compared with «

sinilar coal fired unit.

Cost of pover plant to burn coal end bionass

a, Tavestnent charges

Goal Plant: §683/kv (1978 dollars)

Bionass 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 sane tine additional requirements

44

---Page Break---

WALL be necessary to burn both coals and biomass in the same boiler. It is assumed these two costs cancel out. The cost of the bionass burning plant

is assuned to be the same

the coal plant.

Biomass pover plant $683/kw (1978 dollars)

Investnent charges for a coal plant 1985 dollars is 23.2 wills per kwh. Correction for 1987 gives 27 mille/iw. hr.

b, Fuel Costs*

The fuel coste for bionas

has been figured at $25(1) per ton delivered with a heat content of

15,000.00 BTU per ton, This yield $1.66 per

millions Bev delivered fuel cost (Alex Alexander

information). This cost is taken as 1979 fuel

cost.

Assuming the same carrying charges for a biouase

stock storage of 3 month as was assuned 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 BTU
including 3 month stock storage charges.

?() This include $19.00 per ton production cost and $6/ton transporte-

tion costs. Drying of biouass will beon the field, cut and

Bales or bundles are truck transported from the field to the

over plant storage pile,

-n-

---Page Break---

Levelized fuel cost 1987 dollar, 7 1/4 % escalation.

1987 zuel Cost = (1.70) (1.0725)® meaty

Levelized (35 years) cost!) = 1.75, (2-97)=95.20amtu.

With a plant heat rate of 10,000 Beu/kubr (at 75%

capacity factor).

°

Levelized fuel cost is 52 mille /kwhr.

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)

is = STR (47) + 10Pgq) (LF) (1 + ©)?, wher

8 = sulfur content of coal 2/100

P, = price of Limestone $/ton

TR = coal firing rate tons/hr.

Paq = price of sludge disposal? #/ton

LF = plant coal factor

e+ escalation

Y= years between tine of estinate and beginning

?WD See CHER energy study. For levelization theory. This takes into

account rising coate during plant life.

(2) 1 ton of sulfur requires 4 tons of Limestone to produce 5 tons of

This is combined with 5 tons of water to produce 10

tons of wet sludge, which requires disposal.

120

---Page Break---

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

PL = Pyd = $5.50/ton

8 = .03

?Tr = 200 tons/ar.

LP = 75%

Y= 7 years

e = .08

Substituting above figures in the formula gives, OM Desul~

furization Plant = $5.2 x 108/year

The equivalent:

06M cost in mille/kvh

for Fon systen ?) ig

2 x 106 = 1.91 mitis/iwh

(614,000) (.75) (8760)

?The levelized 35 years OM for FGD System

Leverizes () om cost RGD = (1.91)(1.75)= 3.35.milts

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

determined at ???- 3.3

??? 3.3

plant = 12.0 mills/kwh (1985 cost)

1987 cost = 12 x (1.07)? = 13.7 milte/lwh.

(Q) Coat plant gross capacity is 450,000 kw. Net capacity will be

@

424,000 lew.

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.

73+

---Page Break---

Total cost for Biomass plant 35 years levelized cost.

dollars is:

Investment (eane as coal plant)

Fuel

om

Total (Biomass fired plant cost)

?The comparable cost for a coal plant is

27.0

52.0

13.7

92.7mile/kwhe

120 milis/iwhe

TE the 92.7 milis/kwhr is corrected for the investment of

6.00 million (escalated) research funds invested in objec

tive number one the correction ie rather small. This

correspond to .000357 mills/hr. The R&D funds will be

nore than recoverable in the program. In addition the

multiplying factor in the Puerto Rico economy of a billion

dollars reinvested in local fuel of biona:

versus coal oF oil

nore than pays for the project.

The second and third objective of the program can stand

fon its om economical basis.

Figures 1 and 2 indicate produe~

C. Energy Research Funds Requirements for Bionsss(1)

3979 19801982982 ©1983 1984 ©1985)

1979 Base 2.0 50h 4

Bocalation 1.0 1.08 1617126136147 1,59

Actual 2.26 0.59 0.50 0.54 58.64

(2) Late revision by Dr. A. 6, Alexander indicate smal! additional total

funding requirenents in the order of $930,000.

---Page Break---

zB

is the poss:

Advanced Biomass Programs

For the development of advanced prograne such as flui-

ized bed systems, pelletizing, cycle inprovenents, tech-

nical difficulties of developed methods which needs impro-

venents @ yearly assignnent of 3/4 million in 1986 and

91 million thereafter is allocated (1979 basis). When

escalated at 8% per year the results is:

ADVANCE BIOMASS PROGKAM DEVELOPMENT (MILLIONS §)

1985 19871988 9891990

8 185 2.0 236 2.33

itch Scenario for Bionass

?The primary environmental issues associated with bio-

mass fuel include:

1, Atmospheric emissions quality and quantity and poten~

tial toxicity to humans and other biota.

2. Residue disposal including possible beneficial uses

of the ash as soil anendment:

Secondary environmental research vhich ought to be pursued

Le coupling of sewage and other waste disposal to

the rearing of biomass to aneliorate the fossil fuel subsidy re-

quired for high biomass yields.

Biomass production requires of land and site selection

---Page Break---

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

Tt is difficult to estimate the cost of the research program for biomass program. Hovever, it will be as~ sumed 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 galtons. ?!) 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 a8 2 motor

fuel substitute at prices which will be competitive with

wsoline by the time that a project to produce and market

?ethanol can become ¢ reality. Predicted costs of ethanol

fare in the ranges of $1.00 to $1.25 per gallon. (),

The equipment and facilities required are existent in

Puerto Rico and they will require relatively small invest

ments for conversion.

Cane juice is extracted by conventional sugar cane

Ling tandum, Juice ie clarified in existing sugar will

Ui) Office of theray data

(2) Sugar crops asa source of fuels - D0E - 1978

---Page Break---

clarifiers and rotary vaccum cleaners and concentrated to

about 20% total sugar content. Fro this step on a mo~

dification is required to the sugar will, This modifica
tion 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 10-152 of the
investment cost of a suger 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 go for alcohol production, and

fon the contrary it will be an asset.

?The production of ethanol from sugar cane and of elec~
tricity from the sugar cane bagasse combined with the uti-

Lization of cane wastes 4

a very attractive program.

Ethanol yields today from sugar cane is 15.6 gallons

per ton of green sugar cane. Today the averaye production

of sugar cane in Puerto Rico is approximately 28 tons

a)

acre. Alexander?) has estimated that with a progran

partially optimized for biomass, yields as high as 29 tons

of dry bioma

(216 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 lover'than under controlled

(1) The potential of sugar cane as a Renewable Energy Source for Develo-

ping Tropical Nations ~ A. G. Alexander

?1

---Page Break---

?experimental facilities. Tt is therefore logical to

expect a lover yield of ethanol per acre than the is

aicated figurc

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 biomas

Im order to produce the same gallons of ethanol

equal to the sane gallons of gasoline consumption last

year in P, R. a total of 658,000 acres will be required.

However, because of the lover heat content of ethanol

this will be equivalent to only 60% of gasoline requi-

renents. In addition this plantation could produce the

total energy requirements by the ethanol plant and

nerate 502 of all the electricity requirements for the

year 1982 by burning of baggasse. The acreage indicated

represent _50_% of the total agricultural land in PR.

?The implications to the sugar industry and to the

energy situation in P, R, could be very far reaching

with such a potential progra

However, before any major scale operation is atten-

ted it is necessary to develop realistic information

Pertaining to all the technical data and economic evalua~

tion of @ project to produce ethanol and bioasss for

electricity.

---Page Break---

B. Program Objectives:

1, Selection of saccharum hybrid candidates for evalua~
?tion 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 oui-
table 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 vill be ready by May 30,
1979.

3. Conversion of a sugar mili to handle 4000 tons of sugar
cane per day and produce 62,500 gallons of ethanol
er day (approximately 2.0% of gasoline consumption
during 1977-78) will require an investment of $1.75-2
million dollars in additional coats plus R&D funds.
?This project is to function in parallel with the bio~
?sass boiler project requiring 1000 tons of dry bionass
(4000 green tons) per day. Project operational by

year 1983,

4. Large Scale Operation ~ Goal for 1986

Ethanol production to equal 11% of 1990 ga-

Soline requirements, Investment cost for a new

ee

(D Asounes growth rate is reduced froa 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.

---Page Break---

facility (optimized) $225 million. Cost could be
Feduced to $60-105 million if existing sugar mills

fare considered. Economics studies of both alterna-

tives are required.In addition optimization studies

of ethanol for electric energy and electric cars

scenarios need to be considered versus ethanol for cars.

b. Blecerical generation with bagasse sufficient

t0 feed 50% of the fuel requirements of 500 % elec

trical machine at 75% capacity factor (equivalent

to 10.7% of the electrical energy needs in the year

1990 as stated under objective nunber 2 of the bio~

?mass progran). Tnvesteent cost equivalent to a

coal fueled electric plant, or $325 millions.

Te was shown that the alternative of direct firing of

ass for electricity generation alone was competitive with coal.

?The combination should yield additional economic advantages.

The agricultural land requirement for both alternative com

bined will be twice the value estinated for biomass alone, because

of the lower yields used,

-80-

---Page Break---

R&D Funds Requirenents

?The estinated RED costs of this project, based on

using existing sugar mill facilities and a total project

cost of $150 millions at 6-72 of cost is:

[ETHANOL R&D PROGRAM FUNDS REQUIREMENTS

1979 Factor Millions

Year _$ millions Escalation § Actual

3980 50 1.08 34

1981 1.00 Lay Lay

3982 1.00 1.26 1.26

1983 1.50 1.36 2.04

3984 1.50 1.47 2.21

1985 1.00 1.59 1.9

1986 0.75 un 1.28

1987 0.50 1.85 93

1988 0.25 2.00 50

1989 0.25 2.16 36

1990 0.25 2.33 58

8.50 12.64

~s1-

---Page Break---

D._Advanced Concepte for Ethanol

Research for the production of ethanol at lover costs

include increasing yield production, new methods of fer~

?mentation and distillation and new cycle optinization methods,

Improvenent of technical difficulties of the first ethanol

plants will also require research funds. For these purposes

1/4 milion dollars signed 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 resulte

ADVANCED CONCEPT ETHANOL FUND REQUIREMENTS (ESCALATED) $ MILLIONS

985 198619871988 19891990

0.86 1.85 20 3.24 3.5

E, Bavironmental Research Scenario for Ethanol

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

product.

-#2-

---Page Break---

Solar Steam

Potential and Economic Implications

Steam can be produced by direct solar concentration, tn the

Production of ethanol as motor fuel substitute for gasoline
there {8 a requirement to the order of 15-24 Ibs. of steam per
gallon of ethanol. Steam can contribute to as a high as 10% of
the cost of ethanol with today 's fuet prices. Reduction coste
could be achievable in the range of 5-72 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
Feduction 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 e receiver. The collector has a concentration

ratio of 5.25, The efficiency of collection of solar energy is estimated at 552 at 350°F steam, It make use of divect as vell 45 diffuse radiation of sunlight. It doesn't require daily track ?ing of the um position and as such is very low cost, efficient collector that can be used to produce solar steam a very low ins~ talled cost.

Presently there is a project to produce steam for the Bacerdt Run Distillery in Toa Baja (Palo Seco), This project is covepon-

sored by Bacardi. The results of this project can be extrapolated

---Page Break---

to large industrial type of installation.

Tee proposed large scale ethanol facility in Section IV will Fequite approximately 100 million pounds of steas per day. As euming all steam requiresents are produced by the solar radiation about 1000 acres of surface will be required to produce all the Steam, Ascuning a utilization of 67% of land a total of 1500 acres

Will be required. It is not logical to assune full production

of stean by solar radiation, because the ethanol facility will

have to operate on « 24 hour basis. One third of the steam re~

?auirenent could be assigned to solar energy.

?Tis will require 500 acres, About 17-20% nore electricity

could be produced by the electrical plant since nov 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 invest=

ent and sell the steam for half the cost of an equivalent of1

fueled plant ($2 vs $4 per 1000 pounde of stean).

3, Progran Objective

Economical feasibility and optimization studies and

Geeten to provide steam in the order of 33 million pounds

Per day £0 an ethanol plant (producing 11.% of the gaso-

Line requirenents by the year 1986).

2 Develop the RED Program to make a reality of ouch a pro-

Sect operational by the year 1986.

84-

---Page Break---

Extend the technology for general industrial uses by the

year 1988 to the use-Level of 5 percent of industry ofl

requirement for the year 1988 and 10% by 1990-1995 4

quirement

RéD Funds Requizenents

?The RED requirements a1

figured as follows:

* So ee

?yn ; oe

-85_

---Page Break---

D. Advanced Concepts for Solar Steam

RAD funds will be required for materials improvement pro-

rans vhich will result from the operation of the first ins~

tallations, efficiency improvement for greater yield per

solar collection area, ete.

The escalated allocation for this progran is.

?ADVANCED CONCEPT YOR SOLAR STEAM FUNDING CESCALATED) (§ MILLIONS)

x 19871988 a 3990

8 185 20 2.16 2.33

Bnvironmental Research Scenatios for Solar St

The same environmental considerations given to the photovol~

tates and cogeneration concepts

plies to the solar steam concept.

---Page Break---

Vi. SIMOURY TABLE OF TOTAL GEER FINDING REQUIREMENTS FoR EUVOLE SCENARIOS

TABLE 6 (Cole. 1-12)

?TOTAL CHER FUNDS REQUIREIENTS FOR

8c, PHOTOVOLTATCS, BIOWASS, ETIAMOL WD SOLAR STEAM RED PROGRAMS

MILLION DoLLARs

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hssi [3.97 81 0 a] 677

1982 3.09 1.26 50 1.26, 7.3

i983 4.09 27 sé 2.06 10.07,

t9ea|s.24 5.08) 38 2.21 wr 15.38

1985)5.06 2.95 su | nse! a | ane [9.62

hose 17 f a | 26] eel ass [a | aziss

hoe? teas [7.40 | 185 nas | .93[tas] 9.70 | a.as | 21.28

hoe 2.00 [4.00 | 2.00 2.00 | 50] 2.00] 4.00] 2.00 | 18.50

1989 2.16 | 1a | 2.16 216 | sé] 3.28) 2.16 | 2.16 | 16.20

1990 235 233 2.33] 8] 3.50) 17 | 2.35 | 14.57

70, T

traisi2s.2 |r0.02| 40.73 | 9.34 5.02) 9.14 | i264) ties! 25.62 | 9.14 | 158.73

(1) Assunes Federal Governnent Participation in a ratio of 4.88 to 1,0, where the Puerto Rico

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

(2) Latest estinate revised by Dr. A. G. Alexander is six million dollars.

---Page Break---

VIL. SUMMARY TABLES

---Page Break---

tase 2

ESTIMATES OF PUERTO RICO'S ENERGY MEQUIREMENTS TO THE YEAK 2000

UNDER PRESENT SOCIU-LcOKOKIC STRUCTURES At) ABSENCE OF

?STRONG R AND D FROCKAM ON ALTERNATE ENERGY SOURCES

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355 Bae 23:9] 92.70, 2330

36:7 35 93:41 36.29, 3390

ars ari 16:9 | 40-78 S305

aaa 38:3) CAECBTS 4635

as:8 20:5 29:60. 3396

ae a9 35.00, 66

308 a 38.75 79

3a ar 335.2 |e Te E86

= 23:7 130-8 [67-96 3295

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Em 142-6] 76.80 ?| ?vos3¢

B75 148.9] 12 12078

20:8 135.2 | 6.00 13347

ea Yez.3| 91.15] 14799

66.6 368.6 | 96-62 ?{ ?v6200

63.3 175.61 y2.6 e016

$155,829,

(1) Statistical Correlations between population and GXP and between Gx? and

Bloctrical Energy Generation. Correlation 998. Seo hypendie a

{2) Gasoline Consumption growth projected conservatively between 21/2 - 3%

Ber year va. 6.6% actual. Nore accurate predictions to ve: inclused Sn

Caen Energy Studies

(9) Industria needs projected at 5% per year grovth. More accurate predic~

ons to be included in CEER Energy Svodies,

(4) uel oii proces escalation indicated i approximately 1960-85: 14.32/year;

1985-90: 11% year; 1990-95: 6.8E/year and 1995-2000; 62 year,

---Page Break---

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SCIBDWLE OF PROPOSED SCENARIOS PROG ODBC

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(1) ne tease 9-S00m base toed unkes will bo required in the period considered.

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FOSSIBLE MILLIONS BARRELS OTL SAVED WITH PROPOSED SCENARIOS

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(2) estimated 80 habe per ton of (S18 moisture) boggase.

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TABLE 5

POSSIBLE CHER REVENUES FROM PUES TAX RED LAW

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SCENARIOS

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1961] 75.20 6:77 10-47

1982 77-80

1983 | 2.20

1984 | 86-10. T37 [ss

3985] 09-37 Tiaras

1986] 87.76 73.16-[ar

1987] 65.96 2:05[-37

7988] 85.53 12:83 [33

3989] 85.40 2.81 [30

7390" 12.02 [27

399% 1292 126

1992 13.71 [9a

1993 13.35 [-72

7994 73.92 [31

7995) 13.4920

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START-UP YEAR

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APPENDIX

LONG RANGE FORECAST OF ENERGY NEEDS IN PUERTO RICO

CENTER FOR ENERGY AND ENVIROMENT RESEARCH

UniveRsrry oF PUERTO RICO

---Page Break---

APPENDIX &

LONG RANGE FORECAST OF PUERTO RLCO'S ENERGY NEEDS

ELECTRICAL ENERGE FORECAST

AL General

Tue problen of forecasting long range estimates of energy

use is a rather difficult cask because of all the uncertain~

ties involved in the development of new technologies and

?changing habits which vill affect considerably the estinat

?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 sane time provide energy planners with an overview of the next four decades for the adequate focusing of energy alternatives.

GEER interest is mainly in the energy or fuel alternatives Scenarios which are required to power the Puerto Rico socio~ economic developsent ; therefore, the forecasting has been restricted to the total electrical energy generation which is responsible for the fuel consumed in the electrical planta.

Classical statistical regression analysis vere used, (1)

?The approach adapted was as simple as possible so as not to

complicate the prediction with cosplex relations and hypotheses

such as postulating saturation functions, ete.

I) Statistics] Methods Foy pecieion Makjng, W.A. Chance 1969.

---Page Break---

?The prediction of energy generation requiresent is recognized

to be based on two main factors:

Population

2 Economic welfare or income per eapita of the population.

The above factors vere be analyzed statistically in
making the prediction, After the mathenatical relationship
were established, then judgenont of past experience and insight
of new technologies and changing habitswere considered to
Select the most appropriate relationship.

The energy prediction vas be based simply on a correlation
between total GNP at constant prices and electrical energy.
The GNP vas, be predicted from the product of population predic
tions, times the GNP/capita prediction at constant prices. Popu-
Jations have already been predicted by the Planning Board up to the
year 2000, GUP up to the year 1983. Our predictions vill be,

therefore, somevhat uncertain for the period 2000-2020.

B Population

Population is a very sensitive variable in the prediction of

energy needs. Different government prograns, economic welfare,

social and religious groups' attitudes may influence to a certain

degree, the population grovth. Meléndez (2) indicates that the

Srowth rate of the econoay of a nation responds better to a moderate

#¢ in the population, than to a rapid grovth rate as is the

Present case concerning Puerto Rico, where population is doubled ia

??_?_ he .

@ Goaterencia sobre Econoata y PoblaciSn, De. Janes A. Santiago Yeléadex

aa de Suen erencias y Foros: Nin. 4 Departamento de Economies Unieneae,

dad de Puerto Rico, Rio Piedras, Pusrto ties,

---Page Break---

Jess than 35 years, or to a elow population growth rate such as

doubling of population every 200 years. Doubling tines of the

order 50 years in the population is considered moderate and

adequate to help the econoaic growth.

A api

Population growth rate causes severe impact on the

nation's substructure, the balances of resources and requires

higher investments from outside sources, ete. A very slow

Population grovth rate on the other hand can create problem

?8 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 optinal population grovth 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 een mode.

?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 4 linear regression analysis on historical population data, dating back co 1962, and the Planning Board predictions ¥P to the year 2000 as input data to the regression analysis

in which the total number of input points

22, gives the

following equation: y, = 2166.9 + 65.05 x

-99-

---Page Break---

where yp = population in thousands, x = year referred to the 1960

ie) year less 1960, Coefficient of determination of above equation,

+2 = 0.98, indicating a significant correlation of 99%.

?The predicted population calculated in thie manner for? the

Year 2020 will be 6,070,110. The approximate doubling tine 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 ae pointed out by Meléader. ©)

40 exponential regression of population was also attempted.

?The exponential relation gave sane degree of correlation and

coefficient of determination as the linear relationship but the

doubling time of the present population was 35 yeare. Since this

should not be the policy of government as previously indicated

it was discarded. The exponential relationship wa

Population

cauals to 2308.66, tines ?e" elevated to the exponent 0.024, x

having the sane meaning as before,

?The predicted population for the year 2020 vith this

?exponential relation vas 7,300,580. This was dis,

Of the more appropriate linear correlation indica

Population in the year 2020,

ee

G) op. ete,

---Page Break---

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

TABLET ~ POPULATION

BY LINEAR REGRESSION MODEL

ven POPULATION (ettat0Ns)

1979 3.47

1980 3.59

1981 3.65

182 3m

198 3.78

1985 3.92

1990 4.26

1995 4.52

2000 4.67

2005 5.09

2010 5.42

2015 5.75

2020

Economic Welfare

Te 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 4 small or moderate yearly increase. The total GNP at constant dollars to the population growth rate in the rate GNP per capita. The total ONP in current dollars should further reflect any increase ue to the inflation price factor.

should then reflect a yearly increase of at least equal

101.

---Page Break---

?The Gross National Product (GNP) suns up the econonte activities of the country in terms of production of goods an¢ services, The total

consumption of electrical energy by all sectors of the economy is very sensitive to thin variable and can therefore be satisfactority corre lated. Statistical tests can determine hov good the correlation is.

The Planning Board has predicted total CNP values in

current dollars up to the year 1983 as indicated in Table IL below:

TABLE IT ? ECON. sNDEXES

Planning Board Prediction (of GKP)

Current Dollars ($ thousands)

1979 1980 1981 19821983,

Current $ 9835.0 10750 1,693 12,710 13,795

Constant § 4047.4 4298.8 4,549.7 4,814.0 5,090.1

Constant dollars were estimated by assuming a 10 percentage

Points increment in inflation for the year 1979 and 7 percentage points increnent for the renaining years. The 1978 inflation factor relative to 1954 (the year that the Planning Board sed 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 dollare were converted to GNP per capita,

---Page Break---

These data together vith historical data back to the year 1962

were then retrieved by statistical methods. Four types of regres~

?ion analysis were tried, including, Linear, exponential, loge

rithmic and power. The best fit correlated with a 97.5% corre-

lation coefficient or 95% coefficient of determination, This

fit vas: y = 546.87 x77, where: y = GNP/capita in constant

1954 dollars, x = year - 1960,

Predicted values with above equation indicate yearly émpro-
venents in GNP/eapita 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 vas
multiplied by the predicted population to obtain the total
predicted GNP at constant dollars.

Electrical Generation

?The total electrical generation was correlated with the total

GNP giving excellent correlations. Results vere as follows:

1) Linear Correlation: Coaff. of determination 98%; doubling

?Time: 20 year

2) Power Correlation?: Coeff. of determination 98%; doubling

?Time: 11 years

3) log Correlation +: Coeff. of determination 971

doubling

?Time: over 40 years

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

Time: 5 years

---Page Break---

A statiatical test indicated excellent correlations oa all

the above.

Of all of the above correlations the 1og ead exponential

correlations are discarded because of poorer correlations relative

to the Linear and pover correlations and because of the very slow

sand very fast grovth rates respectively. The Linear and pover

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

doubting every eight yi A doubling tine of ?11 years for the

1980-90 decades is therefore, not unreasonable. Doubling tines of

the order of 20 years might be appropriate beyond the year 2000,

Af the sane level of technology and habits are maintained, rt is felt

hovever, that new technologies and new consuser goods will impact

beyond present expectations on further needs of electric power. One

example, could be the development of urban electrical whicles

requiring nightly battery charging. This requirement might offset

the leveling of power growth as predicted by a Lin

ir relationship.

Also, the developuent of new technologies for producing electrical

Power from renewable sources (solar) might bring down cos

enhancing

?an increase in the demand. We, therefore, feel that the power fit

represents an adequate description of future electrical generation

Production.

jiven by, KWHR gen = (0.001294) (cuP)1+96 x 106

where the unit for GiP is million dolla

doliars.

at 1954 constant

~ 14

---Page Break---

Table IIL indicates the correlation data for population, GIP

?and Electrical Energy. The figures given for electrical energy

consumption are comparable to PRWRA forecasts but they tend to be

fon the low side. Power Technology(3) prediction for the year

2000 is 38,261 x 108 KWtIR generation which is comparable to our

Prediction of 42,910 x 108 KwiR within 5z difference.

?The prediction of electrical energy generation for the year 7020, shown in Figure 1, using the above selected relationship is 89,120 millions Kur, 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 @ scale as large as six tines today's denand by the tine vhen ?supposedly sost energy alternatives being researched today could be highly competitive economically. Electrical energy is used Found the clock, hence, large storage systems on direct solar

derived energy must be looked at in perspective.

?(Dy Tong Tange Soles Forecasting Study for the Puerto Rico Water Resources Authority, Kevin A. Clenents and Robert de Mello, Poet Technologies, Inc. ?Schenectady, N.Y. May, 1976.

---Page Break---

?TABLE LIT

(GNP POPULATION AND ELECTRICAL: PRODUCTION CORRELATION DATA

CONSTANT PRICES (1954)

Fiscal Gnr/capita Population ?_?<GNP_?_Electric Prod.

Year S/capita Thousonds ?$ millions 106 KW-hr

2 694 2,228 1683.9 2,570.7

63 736 2473 $820.7 21934.5

ou 768 23523, 1938.9 3,403.2,

65 817 2,568 4099.2 3,819.2,

66 861 25603 1240.6 4,429.8

or 892 23623 1239.4 5,040.7,

68 927 23650 1455.3 51770.9

69 1000 2,685 24684.0 6,654.5

10 1070 2 2,901.4 7,339.5

n 1120 23747 3,075.6 8,513.3

n 1139 23823 3,215.9 10,2280

3 nas, 2,910 354503, 12,778.0

% 1168. 2,991 3,493.6 1,329.3

15 a3 3,076 3,424:7 12)208.9

6 no 3,167 31487.3 12)349.8

n 16. 31266 y644.% 1312904

78 1150 3,338, 3)837-5 13,7559

» 116.6% 3,470 aloa7ias 143611.2

80 1217.88 31530" 4)298.84 15142916

al 1246.52 31650* 41549178 16307:2

2 1294.18 3)720« Gyei4.o* 17519775

85 3310.9 3,920 5,138.7 23,684

90 4377.5 4,260 5,868.15 30,734

95 36.4 43520% 6,492.53 37,483

2000 1439.4 4,670" 6,955.50 42,910

2005 1537.8 51090 77827.40 54,106

2010 1582.5 5,420, 8,577.15 64,748

2015 1624.0 3,750 9,338.00 76,505

2020 1662.8 6,070 10,093.20 89,120

* planning Board Predictions

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